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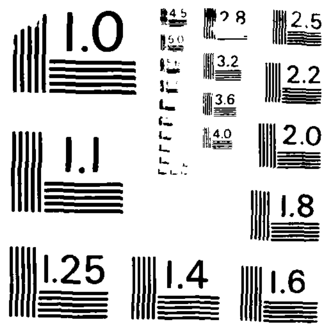

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MODELING THE PERMANENT CHANGE OF STATION
MOVING COSTS OF STRATEGIC AIRLIFT PILOTS

THESIS

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MODELING THE PERMANENT CHANGE OF STATION MOVING COST OF STRATEGIC AIRLIFT PILOTS

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

David M. Percich, B. S.
Captain USAF

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Approved for public release; distribution unlimited

Preface

"He then quite suddenly shifts from manure to mathematics revealing where his analysis has come from" (Box, 1976:193).

I want to thank my thesis advisor, Major Kenneth Bauer. His contribution to my thought process, writing, editing, spelling, rewriting, editing, . . . , were appreciated and needed. All the positive aspects of this research and paper are solely due to him.

Special thanks to Major Joseph Litko my reader and faculty advisor for his input to this research. I am also indebted to Captain David Roberts, AFMPC/DPMYAP, Major Brian Sutter, AFMPC/DPMYAF, Lieutenant Colonel Gerald Ball, HQ USAF/DPXA, and Major Al Thomas, formally of AFMPC, for their guidance and refinements.

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Finally, I want to thank my wife Kathie for her love, patience, understanding, sacrifices, and encouragement during this research effort and the 19 months of graduate school.

David M. Percich

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Abstract

This thesis lays a foundation for PCS cost modeling for the United States Air Force. A SLAM II computer simulation was developed to simulate the career progression of the strategic airlift pilot career field, from accession into the Air Force until their 20th year of military service. The simulation considers the moves that a strategic airlift pilot will experience in a career based on Air Force regulations and current Air Force projections for the career field.

Two response surfaces are developed from the different experimental designs used in the SAL PCS cost experimentation. The first is a second order response surface utilizing the CONUS, overseas short and overseas long tour lengths. The second response surface is a second order surface utilizing the attributes of the strategic airlift pilot career field such as: accession rate, assignment allocations, and tour lengths.

MODELING THE PERMANENT CHANGE OF STATION
MOVING COSTS OF STRATEGIC AIRLIFT PILOTS

I. Introduction

General Issue

The United States Air Force has a worldwide mission, consequently personnel are stationed at duty locations in the continental United States (CONUS) and overseas (OS). Air Force personnel are periodically rotated (sent on a permanent change of station (PCS) move) to new duty locations in the CONUS and OS to ensure military readiness and maintain necessary experience levels in Air Force Specialty Codes (AFSCs). According to a Rand study, personnel are sent on a PCS move because of changing force requirements, completion of overseas assignments, completion of training requirements, separations, and retirements (Doering and Hutzler, 1982:160). For example, during fiscal year 1986, there were 282,481 permanent change of station (PCS) moves in the Air Force (AFMPC, June 1987:2). In order to fund these moves the Air Force must forecast the number of moves for the next fiscal year and estimate the cost of the PCS program.

To estimate the budget requirements for the PCS move program, the Air Force follows the Budget and Fiscal Accounting Classification contained in the Department of Defense (DoD) Budget Guidance Manual, DoD 7110-1M, Part V, Chapter 512. Six move categories are defined for budgeting purposes, they are: operational, rotational, training, unit, accession, and

separation. Operational moves are moves across a body of water. Rotational moves are moves within a theater or within the CONUS. Training moves are moves of entire units due to deactivation or new force requirements. Accession moves are moves that include new officers entering active duty, Basic Military Training, prior service enlistees, and reserve recalls. Separation moves are moves of separating or retiring personnel (Roberts, 1987).

There are two accounting systems that develop the cost for each PCS move category. The Personnel Data System, Randolph AFB, Texas, provides information on the number of PCS moves per category for both officer and enlisted personnel. The Financial Accounting System, Lowrey AFB, Colorado, provides cost data by move category and disbursement. The actual categories and disbursement accounts will be fully defined and developed in chapter 3. The cost data is aggregated and an average cost is calculated per entitlement per move category.

To predict the number of moves for accessions and separations, forecasts from existing personnel programs are used. Unit moves comprise a small number of moves and their total cost is negligible. Air Force training and educational programs provide accurate forecasts for training requirements and the necessary number of moves. Operational and rotational move estimates are based on the past fiscal year's actual move count and are modified for increases or decreases in the projected operational and rotational move requirements. The final estimate of the PCS program is essentially based on the average cost of a move and the average frequency of a move category.

According to the Air Force Military Personnel Center, the Defense Manpower and Data Center (DMDC) cited that the Air Force moved 42% of its people with less than 18 months time on station (AFMPC, June 1987). This assertion caused Mr. Cox, the assistant Secretary for Force Management (ASD/FMP), to request that AFMPC analyze the tour lengths of personnel who moved in the summer of fiscal year 1986. The results of this analysis noted that all but 7.3% of the moves were unavoidable and were within authority of the DoD Directives (AFMPC, May 1987:2). Dr. Armour, ASD/FMP, then requested that AFMPC analyze tour lengths for all moves in fiscal year 1986. The results were consistent with the earlier report on summer moves and the major findings of the time on station analysis was:

> There are common factors that have become clear from virtually all the analysis efforts conducted. Mandatory move situations continue to dominate the PCS program and significantly restrict our ability to reduce the number of PCS moves. Accessions and separations, oversea returnees and their replacements, and moves made from training courses comprise the greatest portion of our PCS program. Without changes in policy for areas such as involuntary extensions of dates of separation, oversea tour lengths, and length of training courses, short moves will continue to impact both the number of moves that we must make, and the average time on station served [AFMPC, June 1987:16].

With Dr. Armour's and Mr. Cox's requests, current budget pressure from Congress and the Armed Forces Sub-Committee, the Assignment System 90 Worldwide PCS Workshop met at Eglin AFB on 11-15 May, 1987. A direct recommendation from that workshop called for "AF/DPXA and AFMPC to develop an assignment tilt model (a model that permits experimentation with the assignment process) to assess the impact of various policy/program changes" (AFMPC, June 1987). Since mandatory moves dominate the PCS program, a methodology must be developed to test

potential policy changes. This recommendation of the PCS Workshop was further clarified by the former Special Assignments Division Chief: Colonel W. J. Hutto when he stated that "a model is needed to quantify the PCS program in terms of moves and costs, to permit experimentation that captures the system's dynamic aspects" (Hutto, 1987).

Problem Statement

Air Force analysts do not have a descriptive model of the PCS program and cannot accurately assess how proposed policy changes or program changes will impact the number and cost of the required moves in the PCS program.

Scope

To build a large scale descriptive model of the Air Force assignment system is beyond the scope of this research. The purpose of this research is to construct a model of one particular AFSC, rather than a scaled-down version of the Air Force. The scaled down version has many inherent problems such as accounting for aggregation and scaling the mean and variance of the cost estimates from the model.

There are thousands of factors that influence the personnel management of Air Force personnel. This research will focus on two types of policies: tour lengths and assignment allocations.

Research Objectives

It is the objective of this research to develop a prototype methodology utilizing a computer simulation of an AFSC with the strategic

airlift (SAL) pilot career field as a guide, that permits experimentation with tour lengths and assignment allocations to quantify the relative changes in PCS costs. A metamodel will be developed to include parameters such as: tour lengths, accession rates, and assignment allocations for training, overseas, and CONUS tours. The metamodel will predict the PCS cost of the SAL career field based on the attributes of the SAL career field.

List of Acronyms

AFAFC - Air Force Accounting and Finance Center

AFB - Air Force Base

AFCC - Air Force Communications Command

AFMPC - Air Force Military Personnel Center

AFO - Accounting and Finance Center

AFOQT - Air Force Officer's Qualifying Test

AFSC - Air Force Specialty Code

ANOVA - Analysis of Variance

ARIMA - Auto-Regressive Moving Average

ATC - Air Training Command

ATRAS - Automated Travel Accounting System

CAROM - Career Area Rotational Model

CONUS - Continental United States

DITY - Do It Yourself Move

DLA - Dislocation Allowance

DMDC - Defense Manpower Data Center

DoD - Department of Defense

FYDP - Five Year Defense Plan

GAO - General Accounting Office

HHG - Household Goods

ISEM - Integrated Simulation Evaluation Model

ISEM-P - Integrated Simulation Evaluation Model Prototype

MAC - Military Airlift Command

MSC - Military Sealift Command

OS - Overseas

PCS - Permanent Change of Station

PCS MIS - Permanent Change of Station Management Information System

PME - Professional Military Education

POV - Privately Owned Vehicle

RMD - Rated Management Document

SAC - Strategic Air Command

SAL - Strategic Airlift

SAS - Statistical Analysis System

SLAM II - Simulation Language for Alternative Modeling

TAC - Tactical Airlift Command

TMO - Traffic Management Office

UNT - Undergraduate Navigator Training

UPT - Undergraduate Pilot Training

USAFAC - United States Army Finance and Accounting Center

USN - United States Navy

WAPS - Weighted Airmen Promotion System

II. Literature Review

The literature review will summarize the applications of analytic mathematical models and computer simulations for military personnel systems. The discussion of each technique will center on the background of the problem and the methodology used to construct the model. The conclusion will summarize all the techniques and compare and contrast each methodology for application to PCS cost modeling.

Analytic Mathematical Modeling

Analytic mathematical models are descriptive or predictive. Bartholomew (1979) states that a descriptive model describes the system in numerical terms that summarize the working of the system. This allows the analyst to experiment with different parameters and understand how change is brought to the system. A predictive model quantifies the system in a functional equation and gives a prediction of the future given the trends of the system. Once the purpose of the model is specified, the type of model: stochastic or deterministic must be specified.

A stochastic model accounts for change in a probabilistic sense. The actual workings of the system are unknown or too complicated, so a probability distribution is assumed to approximate the decisions of the system. If the system's decisions are clearly specified, then a deterministic model may be used to model change in the system.

The three types of analytic mathematical models reviewed in this literature review are the markov flow model, the time series model, and the linear programming model.

Markov Flow Model. Merck and Hall (1971) used markov flow modeling to study the implications of rated supplement jobs (rated personnel serving in non-operational jobs) on the career progression of the rated operations career field. To build the markov flow model, Merck and Hall partitioned the rated operations career field into collectively exhaustive and mutually exclusive states. The states were defined by three factors: aeronautical rating (rated or non-rated), job class (operational or non-operational), and years of service (from less than one year to twenty years, in increments of one year). These factors combinations produce 104 (2X2X26) states with an out of system state added to make 105 states.

In a markov flow model the transition probabilities describe the transition from state j to state i over a discrete time period.

$$p_{ij}=\Pr(\text{state } j \text{ at time } t \mid \text{state } i \text{ at time } t-1)$$

Merck and Hall use the transition probabilities to describe the movement of Air Force officers between states (rating, job class, years of service) over a one year time period. The membership in each state was taken in 1966 and one year later in 1967. The observed movement between states is used to construct the transition ratios: the estimates of the transition probabilities. The transition matrix, shown in figure 1, is constructed using the transition ratios to quantify the movement between all states. The actual 1966 membership counts in each state are used to construct a column vector (S) denoting the initial membership settings of each state. Using the transition matrix and the S vector, markov chain theory can be used "1) to study the actual population distributions and movement over time, and 2) to predict future population distributions" (Merck and Hall, 1971:29). Refer to Kemeny and Snell (1960) for a summary of markov chain theory. An

additional application of markov flow modeling for an Air Force personnel problem can be found in Merck (1965).

$$\begin{array}{cc} & \text{state } j \text{ time } t \\ \begin{array}{c}\text{state } i\\ \text{time } t-1\end{array} & \begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1j} \\ P_{21} & P_{22} & \cdots & P_{2j} \\ \vdots & & \ddots & \vdots \\ P_{i1} & P_{i2} & \cdots & P_{ij}\end{bmatrix}\end{array}$$

Figure 1 Transition Matrix

Time Series Analysis. At the Naval Personnel Research and Development Center, Holmes and Pinciaro (Holmes, 1987) are modeling Navy PCS costs using time series analysis. The emphasis of this research is a means of justification for budget requests to Congress by Military Personnel, Navy.

In 1978 the US Navy and the General Accounting Office (GAO) constructed the PCS Step 1 Cost Tables based on a service member's military rank, number of dependents, and distance moved. Each detailer (the Naval officer making the assignments) is authorized a PCS budget for the assignments to be made in a month. For each assignment the detailer debits the estimated cost of the move, found in the PCS Step 1 Cost Table, from his budget. When the move is completed and the costs are known, the Navy

Finance Center's PCS Analysis Division, Cleveland, Ohio, adjusts the detailer's budget to represent the actual cost of the move (Ball, 1987).

Holmes and Pinciaro are developing two Box-Jenkins auto-regressive integrated moving average (ARIMA) models. The first will predict the number of moves and the second will predict the PCS cost estimate of these moves. The ARIMA models have two types of components: moving average and auto-regressive (Box and Jenkins, 1976). For example, in the ARIMA model that predicts the PCS cost, the moving average component relates the PCS cost estimate to a weighted sum of the previous deviations from past PCS cost predictions, and the auto-regressive component relates the PCS cost estimate to a set of independent previous values of the process.

Linear Programs. If the purpose of the model is to optimize an output of the system represented by an linear objective function and the constraints of the system can be approximated using a set of linear equations, then Linear Programming can be used to find the best solution.

TOPOPS. Knight (1977) and Akam and Nordhauser (1974) use linear programming techniques to study Air Force officer procurement. The Total Objective Plan for Officer Procurement (TOPOPS) was designed by the System Automation Corporation to study "the officer procurement system policy in terms of the possible trade-offs between the quality of entering Air Force officers and the cost of the officer procurement program" (Knight, 1977). The TOPOPS defines three phases of officer procurement: the supply phase, the production phase, and the post commissioning or training phase. The relation of these phases is shown in figure 2.

The supply stage represents the civilian manpower pool available to the Air Force. The size of the pool of recruits is dynamic and depends on

such factors as: socio-economic conditions, Air Force pay and allowances, and the Air Force entrance standards as set forth by the Air Force Officer Qualifying Test (AFOQT). The recruitment requirements of the supply stage define the minimum number of officer candidates that must enter the next phase of the officer procurement, the production phase.

In the production phase the officer recruits are prepared for commissioning by commissioning programs. The model considers commissioning programs such as: the Officer Training School (OTS), the United States Air Force Academy (USAFA), the Airmen Commissioning Program (ACP), and the Airmen Education and Commissioning Program (AECP).

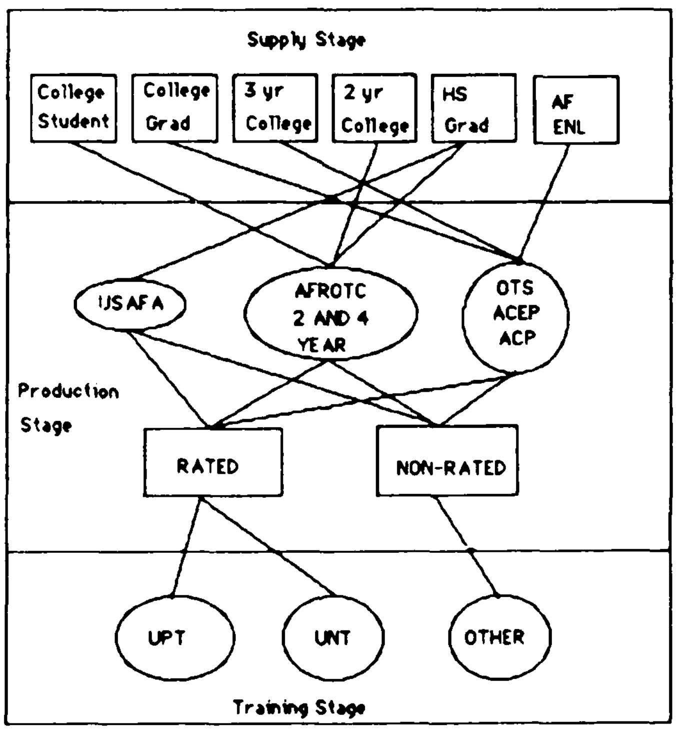

Figure 2 TOPOPS Phases of Officer Procurement

The time to complete these commissioning programs varies from ninety days to four years. In addition, each commissioning program has different education costs, graduation rates, and different retention rates for active duty personnel commissioned by each commissioning program. The output of the production phase is second lieutenants who enter active duty. The last phase has requirements that must be filled by the production rate of the commissioning programs.

In the training phase commissioned officers enter one of four assignments: undergraduate pilot training (UPT), undergraduate navigator training (UNT), a technical training school, or a direct duty assignment. The requirements are then filled as officers graduate from these training schools.

The TOPOPS is a time phased linear program because the procurement of officer candidates is projected over a 5 year time period. The 5 year plan is required due to the length of the different commissioning programs and the length of the required active duty training; varying the length of time until an officer candidate is ready for active duty. The 5 year time frame encompasses the length of the 4 year commissioning program and 1 year of active duty training. A 5 year procurement program is then developed that specifies the number of candidates from each commissioning source and the required inputs to training schools or active duty.

There are two alternative objective functions in the TOPOPS. The first is a cost minimization of the total program cost of recruiting, educating, and training officer candidates. The second is a maximization of the quality of the officer recruits using the AFOQT. The solution will determine the optimal combination of recruits in each commissioning

program per year, subject to system constraints. The TOPOPS has an approximate upper bound of 6,000 decision variables and 14,805 constraints. The constraints are grouped into 5 distinct classes. The first constraint class controls the quality of recruits by using minimum scores on the AFOQT. The second constraint class considers the budget requirements and limitations of each commissioning and training source. The third class of constraints limits the minimum and maximum number of recruits from each commissioning program. The forth class of constraints sets the number of recruits needed after the training phase, to fill active duty jobs. The last set of constraints considers the minimum supply that is required for the entire five year procurement program.

Goal Programming. Linear programs can solve one goal of a system such as cost or utility optimization. But when there are multiple goals, as in personnel systems, a technique called goal programming can be used to find the best solution. Goal programming attempts to choose the value of the decision variable such that the deviation from the goals are minimized (Wu and Coppins, 1981:358). Thompson and Siverd (1979) describe a personnel assignment problem that assigns personnel with varying skill levels. Variables are defined in table 1 to quantify the inventories of available personnel.

Table 1 Variables in Goal Program

x_{im} = number of personnel in skill category i in unit m
x_{bm} = number of personnel in base skill in unit m
y_m = maximum personnel strength for unit m
d_{im} = desired ratio of personnel in skill category i to personnel in skill category b in unit m
f_{im} = fraction of unit in personnel ceiling (y_m) filled by skill i personnel at the desired ratio d
s_i = total number of on-board personnel in skill category i

Thompson and Siverd formulate the goal program as

$$\min \beta \sum_i \sum_m \left[\frac{x_{im}}{x_{bm}} - d_{im} \right]^2 + (1-\beta) \sum_m \left[\sum x_{im} - y_m \right]^2$$

subject to:

$$\sum_i x_{im} \le y_m \quad \text{for all m} \qquad x_{im} \ge 0$$

$$\sum_m x_{im} \le S_i \quad \text{for all i} \qquad x_{bm} \ge 0$$

$$d_{im} \le \frac{x_{im}}{x_{bm}} \le h_{im} \quad \text{for all i, for all m} \qquad 0 < \beta < 1$$

The coefficient β is a user specified weight that represents the importance of the fit of personnel to jobs or the fill of the number of jobs open. Thompson chose to minimize the squared deviations from the goals forming a non-linear, quadratic programming problem. A non-linear pattern search technique (Hooke and Jeeves, 1961:212-229) is used to find the solution.

<u>Networks</u>. The Navy currently uses a manual process to assign people to jobs. At the Naval Personnel Research Development Center Liang (1986;1987) has detailed many network formulations for the Navy to solve the problems of large numbers of assignments, minimizing PCS costs, and

filling jobs with the best qualified personnel. In the formulations there are two types of requirements: macro and micro (Liang and Lee, 1985:371-377). The macro requirement ensures that the allocation of personnel to major groups are met. In the Navy, the macro requirements may be manning levels at divisions or training class slots that must be filled. The second requirement is a micro goal, the decision that determines the best choice of an applicant for a specified job. The detailer must assign the best suited people to jobs, but must also meet force wide allocation requirements.

For example, in figure 3, Liang and Thompson use a network diagram to represent a current Navy assignment problem.

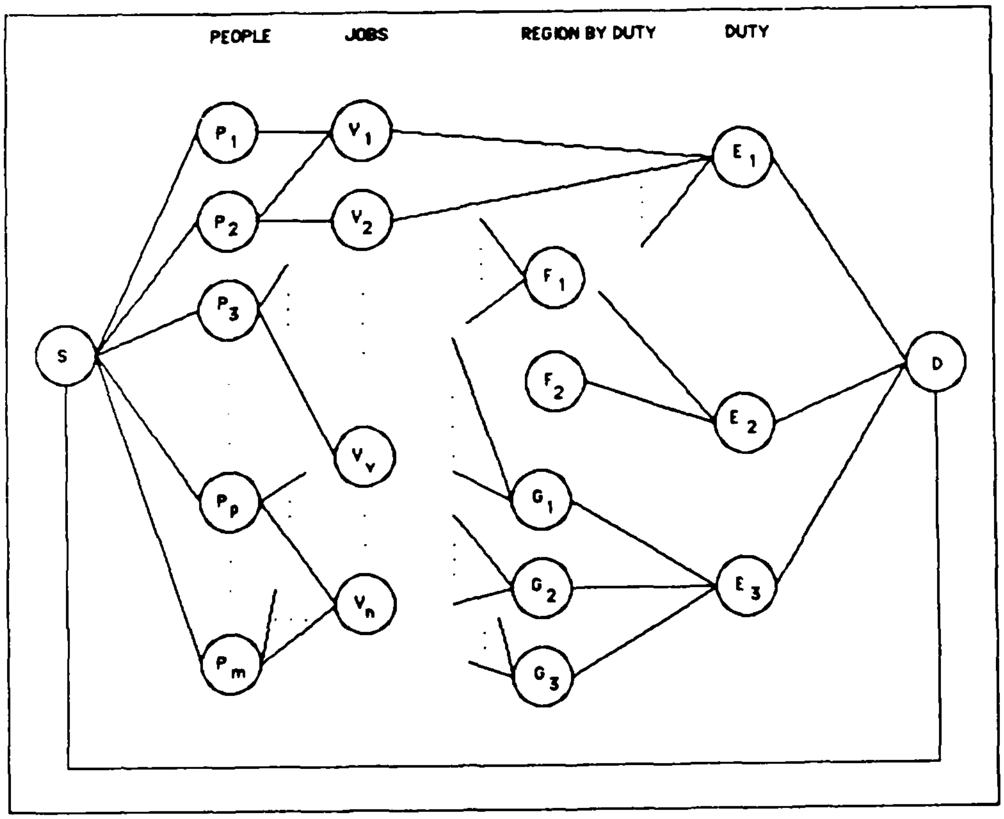

figure 3   Navy Assignment Network Diagram

. The micro goals are modeled by the P nodes $\{p_1, \ldots, p_m\}$ representing the available people for assignment. The V nodes $\{v_1, \ldots, v_n\}$ represent the job vacancies. The macro goals are modeled by nodes E, F, and G. The E node represents the duty type, the F node denotes the region of sea duty, and the G node denotes the type of shore duty. The purpose of each node is shown in table 2

Table 2 Node Representation

E_1 = duty 1 (special duty)
E_2 = duty 2 (sea duty)
E_3 = duty 3 (shore duty)
F_1 = =region 1 (Pacific) for duty 2 (sea duty)
F_2 = region 2 (Atlantic) for duty 2 (sea duty)
G_1 = region 1 (Pacific) for duty 3 (shore duty)
G_2 = region 2 (Atlantic) for duty 3 (shore duty)
G_3 = region 3 (CONUS) for duty 3 (shore duty)

If a person is qualified for a job, an arc will connect the P node to the V nodes. Each job is connected to an F or G node to model the type of duty and location, and the E node models the aggregate duty requirements. Each node has a demand that represents the actual allocation requirements of personnel in each type of duty in each region. With this network diagram it is straight forward to construct an node-arc incidence matrix that represents the conservation of flow constraints of the network. The matrix will be constructed in the following manner.

$$a_{ij} = \begin{cases} 1 & \text{if arc } j \text{ is directed away from node } i \\ -1 & \text{if arc } j \text{ is directed toward node } i \\ 0 & \text{otherwise} \end{cases}$$

The decision variables of the objective function denotes the choice of an arc. The arc cost for the arcs connecting the P and V nodes represent the PCS cost of the assignment. For the arcs connecting the V, E, F, and G nodes, the decision maker must specify coefficients that depend on the ranking of importance of the allocation goals with an opportunity cost associated with the decision. With this formulation a classic minimum cost network flow program is solved with well known algorithms (Jensen and Barnes, 1987).

This basic formulation can be generalized by considering cohorts of personnel in place of specific individuals, and the arcs can be generalized to include cost and capacities. Liang (1986) used this approach in the Enlisted Personnel Allocation and Nomination Systems (EPANS). A similar type of network formulation was used in the Aviation Requirements Study (O'Conner, 1982), in a transshipment model for a personnel system (Thompson, 1978), and in a Rand study to estimate military rotation requirements (Durbin and Wright, 1967).

Computer Simulations. Two types of computer simulation models are reviewed in this literature review. The first type is the discrete-event computer simulation. The second type is the continuous computer simulation.

Discrete Event Simulations. Pritsker states that "discrete simulation occurs when the response variable changes discretely at specified points in simulated time" (Pritsker, 1984:52). The states of the system change only at event times, with the system remaining constant between event times. A simulation of the personnel system changes only at specified times when a promotion, PCS move or other event changes the

attributes of the personnel being modeled. For this reason discrete-event simulation is a popular approach to personnel system modeling. The two discrete event computer simulations reviewed are the Career Area Rotational Model (CAROM) and the Integrated Simulation Evaluation Model Prototype (ISEM-P).

CAROM. The CAROM is a Fortran based, large scale entity type simulation that uses Monte Carlo techniques to study the career progression of airman in the United States Air Force (Looper, 1975:5-6). Looper states that the CAROM was designed to "simulate the accession, grade and skill promotion, reassignment, and attrition of enlisted personnel within a single AFSC on a monthly basis for up to 30 years" (Looper, 1971:6). The motivation for building the CAROM resulted from enlisted rotational imbalances between the CONUS Air Force bases and Southeast air bases during the Vietnam conflict (Looper, 1987). The Air Force experienced shortages in critical AFSCs in the CONUS and then in Vietnam. These shortages flip-flopped between the two theaters, causing manning problems. The CAROM was designed to be a policy evaluation tool which may be used to investigate the interactions in the personnel management of an AFSC.

The CAROM is a large computer model that requires an extensive data input. Personnel records are input at the start of the program to build a 30 year inventory of personnel. At each simulated time advance (1 month) new records are input to simulate the accessions into the AFSC. For each entity in the model, 20 attributes are maintained as shown in table 3. To simulate the career progression of an airmen, the CAROM models 4 personnel functions: grade promotion, skill upgrading, separation, and assignments.

Grade promotion is accomplished by checking the eligibility of each entity for promotion according to the time in grade, time in service, and the skill level requirements of the next grade. The promotion quotas can be generated to fill vacancies in the AFSC at the next grade or by an "equal selection method" (Looper, 1971). The equal selection method is a ranking of the entities by a promotion score. The weighted airmen promotion system (WAPS, circa 1973) is simulated to develop the promotion scores. The order of the ranking will depend on a user specified equation that will weight the WAPS variables.

Table 3 CAROM Entity Attributes

1. Date of enlistment
2. Estimated date of separation
3. Date of rank
4. Current assignment category
5. Projected tour completion date
6. Number of previous remote tours
7. Date of completion of most recent remote tour
8. Number of previous special tours
9. Date of completion of most recent special tour
10. Number of previous long tours
11. Date of completion of most recent long tour
12. Number of previous CONUS tours
13. Date of completion of most recent CONUS tour
14. Skill level
15. Grade
16. Number of months at current skill level
17. Specialty Knowledge Test (SKT)
18. Promotion Fitness Examination (PEE)
19. Airmen Proficiency Rating (APR)
20. Decoration score
21. Unspecified factor 1
22. Unspecified factor 2

[Looper, 1979:15]

The skill upgrading for each entity is done in a probabilistic manner by considering the grade and minimum time in skill.

The model simulates attrition in an AFSC using probabilistic branching. Eight different types of attrition are tracked in the CAROM, they are: exceptional attrition such as death, a category defined as an exceptional attrition rate, up or out for time in service or grade, 30 year mandatory retirement, voluntary retirement from 20 to 29 years, normal expiration of service, tour completion early outs, and a category that was not specified.

In the assignment process, the CAROM first determines the assignment eligibles. To be considered for an assignment an airmen must have met the tour completion date and other minimum requirements. There are 4 different types of tours: 1 CONUS and 3 non-CONUS. For each type of tour, there are a maximum of ten different tour lengths available. All CONUS tours have a minimum service time in which airmen may not necessarily be reassigned. The other non-CONUS tour types all have mandatory assignments when the tour if completed.

To assign entities to jobs, the CAROM solves 2 linear programming problems. The first problem is to maximize the fill of those eligible for assignment to job vacancies by grade and skill. The second problem is to maximize the fit of those assigned, selecting the entities with the best attributes for the job. Both linear programming problems are solved by the Ford-Fulkerson, primal dual network flow algorithm. When a shortage of airmen exists and all job vacancies will not be filled, airmen are assigned to smooth out the shortages and maintain a desired manning level.

The CAROM is fully tested, verified, and validated and currently is maintained by the Air Force Human Resource Laboratory, Brooks AFB. The CAROM models the personnel management of 1 AFSC, in the next simulation the idea was to model the entire personnel system of the Air Force.

ISEM-P. The Integrated Simulation Evaluation Model Prototype (ISEM-P) is a large scale aggregate simulation, written in Simscript II.5. Rueter states that the full scale Integrated Simulation Evaluation Model (ISEM) is meant to model the entire Air Force personnel system. The ISEM-P was built to demonstrate the usefulness, applications, and technical feasibility of building the full scale ISEM.

Rueter simulates the 3 components of the Air Force Manpower and Personnel Center: manpower, personnel, and training. These 3 component enable the Air Force to accomplish the objectives established in the Five Year Defense Plan (FYDP).

The manpower component of the AFMPC determines the demands for skilled personnel in each AFSC. The personnel component ensures and maintains an adequate supply of personnel with skill and expertise levels to meet the demand requirements of the manpower component The personnel component must ensure the demands of the FYDP are filled on a time schedule that ensures military readiness and consistency with established career progression guidelines. The training component is responsible for recruiting and training personnel to replace the personnel leaving the inventory due to retirement or separation. The central assumption of the ISEM is that "the manpower, personnel, and training component of the AFMPS can be viewed as parts of a large information feedback control system" (Rueter, 1981:10). In the full scale ISEM model, the feedback system would

consist of 5 modules, shown in table 4. In the prototype version (ISEM-P), the national labor market and the evaluation system are not included due to the level of complexity and the cost of the computations to represent these functions. The remaining 3 modules, the policy information control, personnel force structure, and the training and transportation pipelines comprise the two submodels of the ISEM-P: the aggregate submodel and the assignment submodel.

Table 4 The ISEM Modules

1. A POLICY/INFORMATON/CONTROL (PIC) Module, representing the data gathering, information processing, and decision-making aspects of the AFMPS.

2. A PERSONNEL FORCE STRUCTURE Module, representing the stock of Air Force personnel, aggregated into as many categories as are relevant to the PIC decision procedures.

3. TRAINING AND TRANSPORTATION PIPELINES, representing the flows of personnel from one category to another, and the processes that implement these flows.

4. A NATIONAL LABOR MARKET Module, representing the changing mix of sources and sinks for personnel in the world outside the Air Force.

5. EVALUATION SYSTEM, comprising a collection of measurement and report generation procedures displaying the performance of the AFMPS and each of its components over time.

[Rueter, 1982:10]

The aggregate submodel "simulates AFMPS force structure planning and adaptation at a relatively cumulative level" (Rueter, 1981:20). The

goals of the aggregate submodel are "to provide personnel, of the right kind, at the right time, in sufficient quantity to staff mission functions" (Rueter, 1981:20). The aggregate submodel operates on a yearly cycle and performs 5 basic operations detailed in table 5.

Table 5 ISEM-P Functions

1. Convert the mission plan into manpower requirements, then transforms the requirements into detailed authorizations.

2. Projects the expected state of the inventory after anticipated attrition.

3. Formulates promotion, training, and recruiting plans designed to change the state of the inventory to conform to the detailed authorizations.

4. Removes actual separations losses from the inventory.

5. Applies the formulated plans to the inventory.
[Rueter, 1981:17]

The missions that the ISEM-P tracks are: flying, training, flying support, and base support. In the model there are thirteen CONUS bases and four overseas bases. The demands of ATC, MAC, SAC, and TAC are used to generate missions and requirements. The FYDP is used as the guideline for yearly manning authorizations, yearly mission requirements, and end strength authorizations for officers and airmen inventories. The grade structure is broken down into 5 enlisted and 5 officer grades, with 51 enlisted AFSCs and 40 officer AFSCs in the model.

The purpose of the assignment submodel is "to simulate the decision procedures that produce assignment orders" (Rueter, 1981:28). In the assignment submodel personnel flows are projected 9 months in the future,

on a monthly basis. The personnel groups are classified by skill and grade and then distributed to bases. Cost minimization is achieved in simulated policies that control the opportunity cost associated with personnel shortages and excess expenditures from personnel surpluses.

The ISEM-P is a prototype model for the larger ISEM. The full model has not be approved for development. The prototype is currently maintained at the Manpower and Personnel Division, Brooks AFB, Texas.

Continuous Simulation Models. A continuous simulation model is a model in which the dependent variable varies continuously over simulated time (Pritsker, 1984:52). To model the continuous change of the model differential equations are used to determine the value of the dependent variable. Lawson (1982) used a continuous simulation to model the personnel inventory imbalances of enlisted AFSCs in the Air Force Communications Command (AFCC). The purpose of his model was to experiment with policies controlling the flow and distribution of enlisted personnel and to correct the imbalances in the AFSC between the CONUS and overseas bases. The model is written in Dynamo and uses the concepts of the Systems Dynamics School (Pugh, 1976).

Lawson assumes that there are 10 goals of the airmen assignment and rotation system, these are detailed in table 6. Lawson then models the relationships and feedback of the 10 goals using difference equations.

Table 6 Lawson's Goals of Assignment and Rotation

1. Sufficient assignments
2. Cost minimization
3. Non-voluntary PCS minimization
4. Morale maximization
5. Minimize separation rates to an acceptable level
6. Maximization of CONUS time between involuntary overseas tours
7. Minimize number of remote tours
8. Minimize involuntary overseas time
9. Skill level/experience distribution
10. Maximize total manning percentage

Conclusion

The first step for any human resource modeling is to determine "how to describe people and what type of aggregation scheme to use" (Rostker, 1984:189). Sometimes the correct level of detail and aggregation is straight forward (such as a military rank of a member in a study on a promotion system) and sometimes a hypothesis and detailed data review will guide the modeler to the best choice of detail and aggregation. At this point, not much information is known concerning PCS costs. The important factors that drive PCS costs (such as: the differences in costs for geographic regions, number of dependents, and military rank) are not known and reliable PCS cost estimates do not exist. This poses a problem for a PCS cost modeling effort. The choice of a markov flow model or linear programming model assumes that the important factors and costs of the PCS system are known, because this information will drive the formulation of the model. The states in a markov flow model are straight forward to set up and the objective function coefficients (PCS costs) and the proper constraints are easily formulated in a linear program. Not having this information poses a problem for analytic mathematical techniques.

However, even if this information could be hypothesized, an additional problem exists. Both the markov flow model and the linear programming model solve the long-run, steady state solution. Although the long-run implications are in themselves important, the long-run analysis ignores the fact that "people learn and modify their behavior in response to changes in both exogenous and endogenous factors" (Rostker, 1984:189). Ignoring how people will react and change their behavior (such as retention rates) will quickly damage a model's credibility.

Not much promise for this research is found in a predictive model such as a time series analysis model. Haggstrom has detailed many problems with the use of historical data for predictions.

> The formulas derived from historical data may be distorted because of incorrect specifications of the functional form of the fitted equations, the exclusions of important missing variables, or biases in the data resulting from inaccurate, incomplete, or contrived historical records. Moreover, the method depends upon a cause and effect relationship between the independent variables and the measures of output [Haggstrom, 1975:10].

There is also the problem of experimentation and sensitivity analysis. Time series analysis does not permit a means to experiment with policies from a specified time series model. All that is found is a functional relationship between historical data trends and a predicted value. In addition, the coefficient estimates of the model only measures the partial effect of a variable, becuase the data is not orthogonal. Furthermore "depending on the degree of non-orthogonality in the data, the least squares estimates of the ßs may be very far from the true coefficients" (Montgomery, 1979:66).

Simulation seems to be the best approach to adopt at this particular point in the PCS cost modeling effort. Although the data is not specified

and the modeler runs the risk of a "garbage in/garbage out" model, the modeling effort will direct and focus the research on which factors seem promising to study that describe the PCS system and suggest future modeling efforts.

III. Background: Data and Model

The purpose of this chapter is to explain how the SAL PCS cost simulation is developed from existing data. All assumptions of the data, both explicit and implicit, will be fully explained and discussed. Next there is a narrative review of the model explaining how important aspects of the SAL career field management are developed and implemented for use in the model. Finally the intended use of the model will be discussed.

The Data

The two types of data used in the SAL PCS cost simulation are the PCS cost data and the SAL personnel data. The review of the cost data will summarize how the PCS moving costs are defined, collected, and stored in the computer databases. The SAL personnel data review will summarize the career development and personnel data of the SAL career field.

PCS Cost Data. The cost of a PCS move can be decomposed into 2 separate costs: the household goods cost and the entitlement cost. The household goods cost is based on the cost of the transition, packing, unpacking, crating, warehousing , and any temporary or long term storage charges of the household goods shipment. If the move involves crossing a body of water then additional costs such as: movement of a privately owned vehicle (POV), and any port handling charges are included. When the move is completed, an additional charge may include the claim for damage to the household goods or POV against the moving company of the government.

The second component of the PCS move cost are the entitlement payments to the service member and dependents. Entitlement payments are

intended to defray the cost of travel, lodging, and meals for the member and dependents. Special allowances, such as the dislocation allowance (DLA), help defray the cost of moving. Travel cost is the actual fare for travel by rail, air, ship, or bus. Mileage cost defrays any use of a POV by the member in a move. Per diem cost defrays expenses for meals and temporary lodging while in transit to the new duty location. Lodging cost defrays the expense of temporary quarters at the new assignment until permanent quarters are found. These costs comprise the entitlement cost category.

An option for all Air Force members is a Do-It-Yourself-Move (DITY). Instead of having a commercial moving company perform the move, the Air Force will reimburse the member for doing the move himself. When a DITY move is performed, the member is responsible for all transportation, packing and unpacking of the household goods. The service member is then paid an incentive payment to accomplish the move.

All move costs are collected on the government bill of lading (GBL) and travel vouchers, both supplied by the base Accounting and Finance Office (AFO). The data is collected, automated, and maintained in Air Force and Department of Defense (DoD) databases. The next section will discuss how the cost data is maintained and explain the different PCS cost databases.

PCS Cost Databases. Each Air Force base has 2 offices that collect PCS cost data, the AFO and the traffic management office (TMO). The AFO collects all expenses of member and dependent costs and each move's household goods cost. The TMO maintains the storage and DITY move cost. The total cost of each move, calculated from the GBL and travel vouchers, is then split into separate cost categories that are dictated by fund cites. All attribution to a specific move or move class is lost when the total cost is

divided into cost categories. The costs are collected in cost categories such as: storage cost and household goods cost. The different cost categories are then automated to the Automated Travel Accounting System (ATRAS) by the AFO, and then forwarded to the Air Force Accounting and Finance Center (AFAFC) at Lowrey AFB.

A separate and independent PCS cost collection database if the Defense Manpower Data Center (DMDC). The DMDC is a DoD database that maintains moving cost data. The DMDC collects the household goods moving costs represented on the GBL keyed to a individual service member, recording information about the member such as: the social security number, branch of service, the pay grade, and information about the move such as: the origin and destination areas. In addition all records are maintained at the United States Army Finance and Accounting Center (USAFAC) in Indianapolis, Indiana.

The records of any movement of household goods or member travel by government conveyance is maintained at the Military Airlift Command (MAC) or the Military Sealift Command (MSC). The payments to service members from damaged household goods or POVs is maintained by the HQ/JAAC, Bolling AFB.

At one time a consideration of this research was to construct a large database of moving cost data keyed to a social security number with the total costs represented in one entry, along with all the attributes of the move and the service member's personnel data. However, using the present methods of PCS cost collection and storage a construction of a large data base of moving costs is nearly impossible. The problem begins when the AFO collects move costs. The cost of each move is regrouped into cost

categories by grade such as: household goods cost and travel cost (AFMPC, 20 Apr 87). When the data is regrouped, attribution to a particular move is lost, making it impossible to develop a cost for that move. The second problem concerns the nature of the database used to record PCS costs, because the ATRAS and AFAFC maintain transitory databases: a database that records move costs as the data arrives. A move may have numerous entries and it cannot be known when all costs for a particular move are gathered. The third problem exists because some costs (such as DITY) are not automated and are sent directly to the USAFAC. The search of these records if too expensive and not accurate. Finally, if a method of reconstruction is attempted, there is no way to validate the database. For example, the actual cost of a move cannot be validated, only the methodology of the construction of the database. If the cost data existed to validate the cost databases, the database would not need to be constructed.

There is an effort in the DoD to develop a consolidated database that identifies PCS costs. This effort, the PCS Management Information System (PCS MIS) would change the current PCS cost collection system (AFMPC, 20 Apr 87). The PCS MIS is currently in the review stage and will not be ready for a considerable time. For these reasons, the present method of collection of moving costs cannot be used to develop moving costs for the SAL PCS model.

It is ironic that in a model of PCS moving costs, the most important data requirement is unavailable. To circumvent this problem, the moving costs for the SAL PCS model will be developed from the United Sates Navy (USN) Step 1 Cost Tables. The Step 1 Cost Tables were developed by the USN and the General Accounting Office (GAO), when the Navy PCS budget for 1976

fell far short of the actual PCS expenditures. The tables develop an estimated PCS cost by rank and number of dependents, from a present duty location to the new duty location. A cost developed from the table is the estimated total cost of the PCS move, both household goods and entitlement. The Step 1 Cost Tables give Navy assignment personnel estimate for the cost of a PCS move. For the SAL PCS cost model, the USN Step 1 Cost Tables will serve as a guide for the PCS cost development in the model.

Career Progression and Assignments. The definition and structure of the desired career progression for Air Force pilots and navigators can be found in the Air Force Regulation (AFR) 36-23. The purpose of the AFR 36-23 is to:

> provide assistance to individual officers, supervisors, career managers, and commanders in determining a logical and attainable career by depicting progression and professional development opportunities for each Air Force officer [AFR 36-23:41].

The AFR 36-23 defines and discusses 5 factors of career progression: the member's military year of service, military pay grade, job assignment, schooling, and education level of an Air Force officer. These factors combine to define career milestones such as: operational assignments, staff assignments, professional military education (PME) and advanced studies that should be completed in an Air Force career. Although not a checklist, the AFR 36-23 suggests permissible choices available to Air Force officers that ensure the officer is promotable to the next higher grade. The AFR 36-23 defines 5 general phases of pilot and navigator development, they are shown in table 7. The SAL career field was chosen because rated personnel are identified by a weapon system code and monitored in operations and

non-operational assignments by the same resource management team (Sutter, 1987). This ensures that career progression is structured and consistent. To develop the actual assignments and authorizations for the SAL career field, the Rated Management Document will be used.

Table 7 Pilot/Navigator Development Phases

YOS	Phases of Development
0-5	Initial
6-11	Intermediate Development
12-17	Advanced Development
18-22	Staff
23 +	Executive

The Rated Management Document (RMD) is a planning guide developed by AFMPC that ensures that the primary weapon systems have an adequate inventory of personnel planned. The RMD determines the projected requirements of each weapon system for up to 5 years into the future, specifying the personnel inventories that will be needed to fulfill these requirements. The accession rate of personnel for each weapon system is developed to augment the attrition of personnel in each weapon system.

The RMD is used in the SAL PCS model to determine the possible assignments for each phase of development and as a guide to develop authorizations in each type of assignment. Using the RMD as a guide the SAL career field has 6 types of assignments shown in table 8.

Table 8 SAL Assignment Types

Force requirements (flying tours)
Training (instructor pilots)
Advanced studies
PME/AFIT
Rated supplement
Accession

SAL Personnel Data. All personnel data of the SAL career field was supplied by Major Brian Sutter, Rated Force Analyst, AFMPC/DPMYAF. Major Sutter has supplied data for retention rates for year of service groups from 1959 to 1986, promotion rates to major, lieutenant colonel, and colonel, and the actual authorizations of assignments for CONUS and overseas flying assignments. The actual personnel data used in the SAL PCS cost simulation were the retention rates and the actual inventory counts in 1986 for each year of service group. The data is detailed in appendix A.

Overview of the Model

The SAL PCS cost simulation will simulate 3 phases of career development: the initial phase, the intermediate phase, and the advanced phase. The initial phase will include undergraduate pilot training (UPT), advanced flying school, and the first operational flying assignments. The initial phase will model officers between their entry into the Air Force until their fifth year of military service. The personnel in this phase are lieutenants and captains. The operational flying assignments will be modeled as overseas short tours, overseas long tours, and CONUS tours. The structure and allocations for each type of assignment of the initial phase are shown in table 9. For UPT and advanced flying school a small loss rate

is assumed. When an entity completes the advanced flight training and is ready for the first operational assignments, all overseas short assignments are filled first, then overseas long tours. When all overseas tours are filled, the entities are the assigned (by default) to the CONUS tours.

The intermediate development phase consists of senior captains and majors (6 to 11 years of military service). The possible assignments for the intermediate phase group are supervisory flying assignments, instructor pilot assignments at ATC, PME or AFIT, or rated supplement tours.

Table 9 Initial Phase Assignments

YOS	Tour Type	Allocations
0-1	UPT	240 per year
1-2	Advanced Flying School	240 approx
3-5	Overseas Short(flying)	17
	Overseas Long(flying)	80
	CONUS(flying)	default

The structure of the intermediate phase is shown in table 10.

Table 10 Intermediate Phase of Development

YOS	Tour Type	Allocations
6-11	Overseas Short(flying)	20
	Overseas Long(flying)	80
	AFIT/PME	55
	CONUS(flying)	725
	Rated Supplement	default

The tours are given by the priority of filling assignments. When the 20 overseas short slots are filled, the overseas long slots are then filled, followed by the AFIT/PME and CONUS slots. The rated supplement tours are the default assignments for the intermediate group.

The last phase of development, the advanced phase, will model the advanced development and staff phases of the SAL career field. This group contains the 12 to 20 year groups, and is composed of majors, lieutenant colonels, and colonels. There are 3 types of assignments in the advanced phase: a PME tour such as War College, operational tours, and staff duty. The actual allocations are shown in table 11.

Table 11 Advanced Phase Assignments

YOS	Tour Type	Allocations
12-20	AFIT/PME	45
	Operations(flying)	50
	Rated Supplement	default

All PME/AFIT slots are filled first, then the operational slots, and the remaining entities are defaulted to a rated supplement tour.

Model Assumptions

The SAL PCS model has major assumptions about the estimates of the PCS move costs, the career progression of the SAL career field and the available assignments for each phase of development. This section will address those assumptions.

Cost Data. The use of the USN Step 1 Cost Tables assumes that the Navy and the Air Force PCS moving costs are similar. Navy bases and

facilities are located predominately on the shoreline, while Air Force bases and facilities are typically located inland; how this effects costs is not known (Ball, 1987). Also the use of the Step 1 Cost Tables in this context assumes that Navy families and Air Force families have similar move attributes, household goods cost, and similar entitlement use. Finally the PCS cost tables develop an estimated cost which is adjusted at a later date with a cost developed from travel vouchers. The Step 1 Table are estimates that were never verified.

Personnel. To develop the career progression of the SAL career field, major assumptions regarding policy and reaction to the policy change by Air Force personnel are made. As Rostker states "people learn and modify their behavior in response to changes in both exogenous and endogenous factors" (Rostker, 1984:189). To begin the retention rates and authorizations from 1986 are used and held constant throughout all runs of the model. This ignores how retention rates change when major policy decisions are made. For example, if a policy change such as retirement beginning after 30 years of active duty service came into effect, retention rates would surely change. In the SAL PCS cost simulation as certain factors are changed (for instance the number of personnel in overseas locations or tour lengths made longer) the retention rates stay constant.

The RMD is used to develop a crude authorization number for different types of assignments to fill training quotas and specify accession rates. The RMD is a planning aid that is annually reviewed and updated that represents the pilot inventory as envisioned by the AFMPC personnel analysts to fill weapon system requirements in the future.

The assignment process of the model has some broad assumptions. For example, consecutive overseas tours are not allowed, and this reduces the number of operational moves in an AFSC. The actual rate of accompanied and unaccompanied moves in the SAL career field is assigned in the computer simulation in an arbitrary manner. The actual number of every assignment type is static. The factors that drive the assignment process are many and diverse, in the SAL PCS cost simulation the factors that drive assignments are overseas tour availability, training slot availability, separations, and completion of a tour. This is a simplistic view of how assignments are made.

Intended Use of the Model

The intended use of the SAL PCS cost simulation is to develop an methodology to model AFSCs to help develop relative cost estimates that were not based on the current data availability. The policies that can be tested in this research are changes in tour lengths, changes in the accession rate into the AFSC, and changes in assignment allocations. This model is not intended to be used to develop specific cost estimates for the SAL career field.

IV. Methodology

The purpose of this chapter is to explain and review the SLAM II network code and the Fortran subroutines that together comprise the SAL PCS cost simulation. After the flow of the model is explained, the techniques used to verify the source code and validate the model are summarized. The chapter will close with a detailed explanation of the methodology used to fulfill the research objectives.

The SAL PCS Model

The SAL PCS cost simulation is written in the Simulation Language for Alternative Modeling (SLAM II) (Pritsker, 1984). SLAM II is an Fortran based, event oriented modeling language that has the capability to model a system using network modeling (SLAM II source code), discrete-event modeling, or continuous modeling; or any combination of these modeling techniques. The PCS cost simulation is a network and discrete-event simulation that models the career progression of the SAL career field, and records the cost of the PCS moves. The model was designed to run fast and permit experimentation with assignments allocations and tour lengths.

SLAM II Network Code. Before the SLAM II network code is reviewed, the attributes of the entities in the model and the SLAM II variables are defined in table 12. During the discussion of the network code, refer to appendix C for a network diagram of the SAL PCS model. The CREATE node creates an entity every two months, or .1667 years. A value equal to XX(6) (39 in this case), the SAL accessions per UPT class, is assigned to the entity in atrib(2). Atrib(2) will be used in the UNBATCH statement to create the 39 entities that represent the accessions into UPT. Each entity has a

2/5 probability of being accompanied and a 3/5 probability of not being accompanied in this move.

Table 12 SLAM II Variable Definition

atrib(1)=year of service
atrib(2)=last tour type
atrib(3)=tour length
atrib(4)=last tour type
atrib(5)=accompanied indicator
atrib(6)=separation indicator
atrib(7)=activity choice

XX(1)=accession move cost
XX(2)=separation move cost
XX(3)=training move cost
XX(4)=rotational move cost
XX(5)=operational move cost
XX(6)=SAL accessions per class

All entities are assigned a moving code (atrib(4)=1, refer to table 15), and a year of service (YOS) of 1 year The EVENT,1 statement calls the MOVE subroutine where moving costs are collected and then the entities are placed in activity 12, the UPT for 1 year A small percentage of entities fail to graduate, 0031, and are separated from the Air Force. Those that graduate are then assigned a new moving code, atrib(4)=2, and their YOS is updated, atrib(1)=2 0 EVENT,1 calls the subroutine MOVE to collect the PCS cost of the new assignment. The entities are then placed in activity 13, advanced flying school, for 1 year. A small number are separated and the remaining entities are assigned to an active duty job. Queue(1) contains the entities being assigned to operational assignments in the initial

development phase. The EVENT,3 node calls the ASSIGN subroutine that assigns an activity number in atrib(7) that will be used in the GOON node conditional branch to fill the activity 1, 2, or 3. Refer to table 13 for the description of these activities. When the activity is complete, 1 branch at the GOON node is taken. Those with an atrib(5) equal to 1 are separated. Those entities with a year of service in atrib(1) less than 5 years are routed back to Queue(1). The remaining entities are routed to Queue(2), the intermediate development phase.

Those entities that have 5 or more years of service and are not separating are sent to Queue(2). Approximately 1/2 are sent directly to Queue(2), and approximately 1/4 of those going to the assign node will have their accompanied status changed. Entities are directly routed to the EVENT,3 node where an activity number, tour length, separation status and move costs are collected. Entities are then placed in one of the activities: 4, 5, 6, 7, or 8, depending on the value of atrib(7). Refer to table 13 for a description of these activities. When the activity is complete, one branch at the GOON node is taken. Those entities with an atrib(5) equal to 1 are separated. Those entities with a year of service in atrib(1) less then 11 years are routed back to Queue(2). The remaining entities are routed to Queue(3).

Entities are routed with a probability of 1/2 directly to Queue(3). Those entities going to the ASSIGN node will be assigned an accompanied status. The entities in Queue(3), representing the advanced development phase and the staff phase, are routed directly to the EVENT,3 node. An activity number is assigned in atrib(7), tour lengths in atrib(3), and an separation status in atrib(5). When an entity completes the assignment, it

is routed to the GOON node. Those entities with a YOS less than 20 years are routed back to Queue(3) and the remaining entities are terminated from the model.

Those entities that separate are routed to the SEP label. A move type of 2 is assigned to atrib(4) and the move cost is collected by the EVENT,1 node call to subroutine MOVE. The entity is then terminated. For reference in this chapter, table 13 details the assignments in the SAL PCS simulation.

Table 13 SLAM II Activity Definitions

Activity No.	Assignment Type	Allocation
1	Overseas short Phase 1	18
2	Overseas long Phase 1	80
3	CONUS Phase 1	default
4	Overseas short Phase 2	25
5	Overseas long Phase 2	50
6	AFIT/PME Phase 2	45
7	CONUS Phase 2	700
8	Staff Phase 2	default
9	AFIT/PME Phase 3	35
10	Operational Phase 3	40
11	Staff Phase 3	default
12	UPT	240
13	Advanced Training	240 (approx)

The moving costs are collected and maintained by the STAT control statements. The collect nodes maintain information on moving costs and activities.

Fortran Subroutines. Fortran subroutines are used to represent the assignment process as described in the model overview from chapter 3. Each subroutine is detailed along with its purpose, logic, and connections to

the SLAM II network code and other Fortran subroutines. Refer to appendix E for the Fortran code.

Subroutine INTLC. This subroutine, called at the beginning of each run ,will initialize all the SLAM II variables in SCOM1 and UCOM1. The SCOM1 common block contains the SLAM II variables that are used by the SLAM II main program. The UCOM1 common block contains the user defined variables and is detailed in table 14.

Table 14 UCOM1 Variables

XOSL=tour length of overseas long tours
XOSS=tour length of overseas short tours
XCON=tour length of CONUS tours
IACCY=number of SAL accession per year
IOSS1=number of overseas short tours in phase 1
IOSL1=number of overseas long tours in phase 1
IOSS2=number of overseas short tours in phase 2
IOSL2=number of overseas tours in phase 2
ITR2=number of training slots in phase 2
ICON2=number of CONUS tours in phase 2
ITR3=number of training slots in phase 3
IOPS3=number of operational tours in phase 3

The READ statement reads the variables in table 14 from the end of the SLAM II network code after each SIMULATE statement. The SLAM II variable, XX(6), is set to the number of the candidates who enter UPT to become SAL pilots. This is calculated by the yearly accession rate in the SAL career field which is divided by 6 and is rounded to the greatest integer. The three DO LOOPS in the INTLC subroutine initialize the current inventory of the SAL career field for year of service group, 1 through 16. Each entity is assigned a current year of service in atrib(1), and placed in the appropriate Queue.

The initial phase entities are then placed into Queue(1), the intermediate development phase entities are placed into Queue(2), and the advanced development phase entities are placed into Queue(3).

The cost matrix is a 5X5X2 array that represent the moving costs used in the SAL PCS cost simulation. The array configuration represent 5 different military ranks, 5 different move types, and an accompanied or unaccompanied status indicator. The move costs were developed from the USN Step 1 cost tables. Since actual number of moves were not obtained, an arithmetic mean was developed for the CONUS to CONUS moves by rank, for accompanied and unaccompanied moves. For the overseas to CONUS or CONUS to overseas moves an weighted average was developed based on the allocations of SAL assignments in foreign countries. The cost array is entered with a move type such as: accession, overseas to CONUS, CONUS to overseas, or CONUS to CONUS, a military rank such as: second lieutenant through lieutenant colonel, and an accompanied status to determine the cost of the move. The cost is then added to the appropriate move category in subroutine MOVE. The actual costs used can be found in appendix B.

The retention rates used in the SAL PCS cost simulation were taken from the actual 1986 inventory look at the SAL career field. For each year group, 1959 to 1986, the membership counts and retention rates from the previous year were recorded. The actual rates are found in appendix A.

The CALL SCHDL statement will clear all statistical arrays at the beginning of the first year using the CALL CLEAR subroutine. This is done to obtain the yearly moving costs from the simulation. Then EVENT 2 is scheduled to clear all statistical arrays every year.

Subroutine ASSIGN. Subroutine ASSIGN is called by the SLAM II network statement: EVENT,3. This subroutine uses the available assignments and allocations, refer to table 13, and fills activities in the SLAM II network statement by assigning the activity's number to the entity's atrib(7). The subroutine branches to the correct phase of development using the value of atrib(1) and places the entity into the correct IF structure. The inputs to the subroutine are the entity's attributes. The output from the subroutine are the value of atrib(3) the tour length and atrib(7) the activity choice. A call is made to the subroutine TOURL to compute the tour lengths, or tour curtailment for the assignment just made. Next a call to subroutine MOVE is made to collect the cost of the move, represented by atrib(2) and atrib(4). Finally, program control is transferred back to the network code.

Subroutine TOURL. This subroutine is called by subroutine ASSIGN. The inputs to this subroutine are atrib(4) the new tour type. The output is the value of atrib(2) the last tour type, atrib(3) the tour length, and atrib(6) the separation indicator. The move types are detailed in table 15.

Table 15 Move Types in Atrib(2) and Atrib(4)

1=accession move
2=separation move
3=training move
4=overseas short move
5=overseas long move
6=CONUS move

If atrib(4) equals 3, the entity is assigned to an AFIT/PME class and the tour length is set to 1 and 1/2 years with no separation allowed. If atrib(4)

equals 4, an overseas short tour, the tour length is set to the current value of XOSS and no separation is allowed. If atrib(4) is equal to 5 or 6, an overseas long or CONUS tour, a tour length of XOSL or XCON is assigned. To determine if the tour is curtailed by a separation, the retention rates are multiplied until the probability of retention, XRET, is less than a sample from a uniform (0,1) random variable. If the value of XRET is greater then XTOUR after the DO LOOP ends, the tour has no curtailment. The variables XOSS, XOSL, and XCON are factors that may be changed during the model runs.

Subroutine MOVE. This subroutine is called by subroutine ASSIGN after the entity has been given an assignment, the tour length has been determined, and the separation status for the new move is determined. A rank is assigned by year of service shown in table 16.

Table 16 Rank Determination in MOVE subroutine

YOS	Rank
0-2	2nd Lieutenant
3-4	1st Lieutenant
5-10	Captain
11-14	Major
15 +	Lt Colonel

The move cost is determined and then recorded based on the value in atrib(2) and atrib(4). The value of IMOVE, the move category, is computed using logic detailed in table 17. The value IRANK was assigned based on the year of service (YOS) and IACC is the current value of atrib(5), the accompanied indicator. A look up in the cost array, COST(IMOVE,IRANK,IACC), is recorded

in the COLCT node and then program control is transferred back to the subroutine ASSIGN.

Table 17 Move Type Determination

Atrib(2)	Atrib(4)	Move Type
0	1	Accession
3, 4, 5, or 6	2	Separation
1, 4, 5, or 6	3	Training
3	3, 4, 5, or 6	Training
6	6	Rotational
4 or 5	6	Operational
6	4 or 5	Operational

Subroutine OTPUT. This subroutine reports the cost and number of moves per year in the SAL PCS cost model. The SLAM II variable CCNUM(I) represents the number of observations at COLCT node I and using CCAVG(I), the average value in COLCT node I, CCNUM(I)*CCAVG(I) represents the year cost in that move category. The program also reports the total number and cost of the year's PCS moves. The total cost of the PCS moves per year, XTOTCST, the total moves per year, XTOTMV, and the inventory, IVEN, are printed to a file. The factor settings of the assignments allocations and the tour lengths are also printed.

Verification

The actual SLAM II network code and the Fortran source code were verified to ensure operation as intended. For each critical decision, the values of the important variables were printed to a log file to ensure the program flow was consistent and logical. The SLAM II MONTR statement

was used during model building to ensure proper operation of the SLAM II network code. Parameters of the simulation were varied across their respective ranges with runs at extreme values to see if the output was logical.

Validation

The idea of using AFR 36-23 and the Rated Management Document (RMD) as a basis for constructing a computer simulation of the SAL career field was discussed with Major Brian Sutter, Rated Force Analyst, AFMPC/DPMYAF (Sutter, 1987). At that time Major Sutter stated that the career field was not structured or managed according to the exact guidance in the RMD. The RMD is a planning document that details future personnel requirements in weapon systems. Rather than use the subjective judgements of the workings of the SAL career field from an AFMPC career monitor, the computer simulation was be built with the guidance from AFR 36-23 and the RMD. The PCS costs cannot be used to verify the model's output since PCS costs are not known. Total moves cannot be used since this information is not readily available, and the total number of moves is dependent on the accession rate and retention rates of the AFSC.

The method of validation that needs to be applied is one of model credibility. Schruben (1980) details this process as presenting the simulation output and real world output to a manager of the system to see if the simulation results are easily distinguishable from the real world data. At this time, not much is known about PCS cost or significant factors of the PCS cost estimation, hence the dilemma of validation.

Meeting Research Objectives

This research has two areas of analysis. In the first area of analysis, experiments will be done to quantify the relative changes in the total PCS cost of the SAL career field as tour lengths are changed. The second area of analysis concerns the the identification of the SAL career field into career area attributes, assignments allocations, and an accession rate into the AFSC, and construct a metamodel to quantify the contribution to PCS costs.

Tour Length Experimentation. The tour lengths for overseas short, overseas long, and CONUS tours may be changed in the SAL PCS cost simulation. Each tour length must be in years, from 1 to 20. The response variable for each experiment will be the total PCS moving cost. The first step in the tour length response surface building is to run a 2^3 factorial experiment with 6 replicates at the center point of the design. The factors and ranges are shown in table 18.

Table 18 Factors and Ranges in Tour Length Experimentation

Factor	Description	low	med	high
A	Overseas long	3	5	7
B	CONUS	3	5	7
C	Overseas short	1	2	3

The Statistical Analysis System (SAS) General Linear Models Procedure (Proc GLM) will be used to construct the Analysis of Variance (ANOVA) table for the first degree polynomial response surface (SAS Institute, 1985). The first order coefficients for the linear model will be found by the SOLUTION option in the MODEL statement. The F statistic for overall model fit will be

used to judge model adequacy (Montgomery, 1984:85-93). Each coefficient estimate will be judged for significance using the F statistic for model factor effects (Montgomery, 1984:223-229). The assumptions of constant variance and normality of the data will be checked with plots (Montgomery, 1984:85-93). Center point runs will be used to calculate the curvature of the data for motivation to build the second degree polynomial (Cornell, 1984:17).

If there is curvature in the data, suggested from rejecting the null hypothesis of a planar surface, a second degree surface will be built. The quadratic model will be built using a Box-Behnken design (Box and Behnken, 1960:455-475). The Proc GLM will be used to construct the ANOVA table. Overall model fit, significance of factor effects using the F statistic, and the model assumptions of normality and constant variance will be checked for the tour length quadratic model.

Metamodel. The metamodel of the SAL career field will initially start with 12 factors. Although the actual number of factors that effect the SAL career field is much greater, in the SAL PCS cost simulation these are the factors that the experimenter can control. The first step will be to identify the statistically significant (and practically significant) factors for the PCS cost estimate. To determine which factors are significant, a two-stage factor screen will be used. (Montgomery, 1979; Watson, 1961) The 12 factors will be grouped into 5 factor groups according to the assumptions that all factors in a factor group move the response in the same direction. The factor, factor groups, and factor ranges are shown in table 19. The factor groups B, C, and D contain the assignment allocations for each phase of the career development. Since these factors are predominantly overseas

tours, with some training and CONUS tours, it seems reasonable to assume that all move in the same direction, increasing the response variable. Overseas tours are usually more expensive and raising the allocations needed in overseas moves moves raise total PCS costs. Factor group E will tend to lower the response variable (PSC cost) as the tour lengths are increased since personnel will move less often. Factor A, the accession rate into the SAL career field, will be the only factor on factor group A. This was done since the factor is assumed to be significant in relation to the response variable (Montgomery, 1979:54).

Table 19 Factor Groups for the Factor Screen Stage 1

Factor Group	Factor	low	high
A	Accession rate	300	400
B	Overseas short 1	10	20
	Overseas long 1	50	100
C	Overseas short 2	10	30
	Overseas long 2	50	100
	Training 2	45	65
	Operations 2	600	800
D	Training 3	35	55
	Operations 3	40	60
E	Overseas short tour	1	3
	Overseas long tour	3	7
	CONUS	3	7

The choice of the factor groups may seem arbitrary, but research by Mauro and Smith (1982) indicates that with the small number of factors and the small factor group size, there will be no problem distinguishing significant effects.

To identify the significant factors for the linear model, a fractional factorial could have been run, such as a 2^{12-4}, resolution IV design. But this would require 256 runs. The factor screen stage 1 with the factor group defined in table 19 requires a 2^5 factorial of 32 runs. Computer resources are scarce, hence minimizing the number of runs will be the binding constraint in choosing all simulation experiment designs.

Proc GLM will be used to construct the ANOVA table to distinguish the significant effects. The F statistic will be used to determine model adequacy, and the F test test will be used to determine the significant factor effects. Plots of the predicted variable versus the residuals will be used to check the constant variance assumption of the residuals and a normal probability plot will be used to check the assumption of normality of the residuals.

The significant factor groups from the stage 1 factor screen will then be run in the stage 2 factor screen. The significant factors in the stage 2 experiment will be identified using a fractional factorial experiment. The surviving factors from the second stage factor screen will then be used to build the linear response surface predicting the PCS cost estimate. The F statistic will be used to judge model adequacy and the significance of the factor effects. All assumptions of the ANOVA will be checked.

The surviving factors from the stage 2 factor screen will be run in some type of fractional factorial (depending on the number of significant factors) with replicates at the center point of the design. The Proc GLM will be used to find the linear response surface, using the F statistic for model fit and the individual F statistic for inclusion of parameters in the model. The first order coefficients will be found using the SOLUTION option.

The ANOVA assumptions of constant variance of the residuals and normality of the residuals will be checked. Replicates at the center point of the design will be used to determine if there is a need for a quadratic model.

The curvature test, if rejected, will be the motivation for construction of the second degree response surface. A Box-Behnken design will be used and the Proc GLM will be used to obtain the parameter estimates for the response surface (SAS Institute, 1984). Model assumptions will be checked, along with model adequacy.

V. Findings and Analysis

The purpose of this chapter is to review the statistical analysis of the experiments performed on the SAL PCS cost simulation. First the technique used to estimate the amount of simulation time needed until the SAL PCS cost simulation reaches its steady state will be explained. For both the metamodel and the tour length model the results of all experiments will be summarized by an analysis of variance. The appropriate model will then be used to generate a response surface to show the interactions between the factors. Finally the fulfillment of research objectives will be discussed.

Model Operation

To estimate the transient phase, 5 independent replications were done using the SAL PCS cost simulation. For each of the 5 replicates with the same factor setting, a run simulating 100 years was done. For each time period, an average "across" the replication was computed to form a graph of the average across the 5 replications. Then a moving average of the observations, 5 observations at a time, was computed to further smooth the graph. This process was used to produce a graph to estimate the transient period for the model "warm-up". From the graphs found in appendix I, it is clear that at about 25 years (simulated time), the model reaches its steady state. For all runs of the model in the experiments, the model's output will be discarded for time period 1 to 25. The observation for an experiment will be recorded at simulation time equal to 25.

Statistical Analysis

The experimentation done on the metamodel will be discussed first, then the results of the tour length model will be reviewed. The designs,

ANOVA results, the model's assumptions and the response surfaces will be reviewed and detailed.

Metamodel. In this section the results of the metamodel's construction will be detailed. The factors that will be tested for the metamodel are the accession rate into the SAL career field, the assignment allocations for the SAL career field and the 3 different types of tour lengths. To begin the analysis, a factor screen will be used to identify the significant factors.

Factor Screening. The 5 factor groups defined in chapter 4 were run in a 2^5 factorial experiment. The factor and factor groups are shown in table 20. The resulting ANOVA is shown in table 21.

Table 20 Factor Groups for the Factor Screen Stage 1

Factor Group	Factor	low	high
A	Accession rate	300	400
B	Overseas short 1	10	20
	Overseas long 1	50	100
C	Overseas short 2	10	30
	Overseas long 2	50	100
	Training 2	45	65
	Operations 2	600	800
D	Training 3	35	55
	Operations 3	40	60
E	Overseas short tour	1	3
	Overseas long tour	3	7
	CONUS	3	7

The hypothesis of equal factor effects was rejected with a p-value of .0001. The significant factor groups in the stage 1 factor screen were factor group A (the accession rate with a p-value of .0001), C (Assignments phase 2 with a p-value of .0001), and E (the tour lengths with a p-value of .0001). These

factor groups will be studied in the stage 2 factor screen. Refer to appendix H for the model assumptions graphs.

Table 21 ANOVA for the Factor Screen Stage 1

Source of Variation	df	Sum of Squares	Mean Square	F	p
Model	5	63.59145	12.71829	385.27	.0001
A	1	24.70746	24.70746	784.45	.0001
B	1	.21071	.21071	6.38	.0179
C	1	1.80171	1.80171	54.58	.0001
D	1	.00261	36.86897	.08	.7810
E	1	36.86897	.03301	1116.85	.0001
Error	26	.85830			
Total	31	64.44975			

The graph of the residuals versus the predicted values shows the effect of the grouped data with respect to the predicted values. Each group tends to one side on the vertical reference line. The assumption that the residuals are distributed normally is a reasonable assumption.

The 3 surviving factor groups, A, B, and E, were decomposed into the original factors. The 8 factors that will be included in the stage 2 factor screen are shown in table 22. These 8 factors were run in a 2^{8-3} fractional factorial. This is a resolution IV design that ensures main effects are aliased with 3 way interactions and higher. These effects (3 way and higher) are assumed to have no statistical significance. According to Anderson and McLean (1984:262), the defining relation for the fractional factorial was:

$$I=ABEGH=ACFG=BCEFH=AECD=CDEGH=BDFG=ADEFH$$

The stage 2 factor screen was run and the ANOVA table is detailed in table 23. The F statistic (F=156.21) has a p-value of .0001, hence the null hypothesis of factor effect equality is rejected. With an alpha level of .05, the significant factors from the factor screen stage 2 are the accession rate (A) with a p-value of .0001, the overseas short tours phase 2 (OS Sht2) with a p-value of .0001, the CONUS tour length (CON TL) with a p-value of .0001, and the overseas long tours length (OSL TL) with a p-value of .0001.

Table 22. Factors in the Stage 2 Factor Screen

A-accession rate (ACC)
B-overseas short tours Phase 2 (OS Sht2)
C-overseas long tours Phase 2 (OS Lg)
D-training tours Phase 2 (Trn2)
E-CONUS tours Phase 2 (CON2)
F-overseas short tour length (OSS TL)
G-overseas long tour length (OSL TL)
H-CONUS tour length (CON TL)

These 4 factors will be used to build a linear response surface to predict PCS costs.

These factors seems reasonable since the accession rate will be used to replace the separating personnel. If the accession rate is increased too much, then the SAL career field inventory will grow larger and more moves will occur. Both tour lengths are significant and this seems reasonable since most of the tours (over 95%) are overseas long and CONUS tours. The significance of overseas short tours for phase 2 may seem reasonable since this comes from the phase of career development with the most personnel.

A plot of the predicted versus residuals shows the assumption of a constant variance of the residuals is reasonable. The normal probability

plot of the residuals shows that the residuals are distributed normally is valid. Refer to appendix H.

Table 23 ANOVA Table for Stage 2 Factor Screen

Source of Variation	df	Sum of Squares	Mean Square	F	p
Model	8	48.71669	6.08959	156.21	.0001
A (ACC)	1	29.99531	29.99531	769.43	.0001
B (OS Sht2)	1	.86260	.86260	22.13	.0001
C (OS Lg)	1	.04129	.04129	1.06	.3141
D (Trn2)	1	.13337	.13337	3.42	.0773
E (CON2)	1	.02078	.02078	.53	.4727
F (OSS TL)	1	.05707	.05707	1.46	.2386
G (OSL TL)	1	3.95518	3.95518	101.46	.0001
H (CON TL)	1	13.65108	13.65108	350.17	.0001
Error	23	.89662	.03898		
Total	31	49.61331			

<u>Linear Metamodel</u>. To build a linear response surface, a 2^4 factorial with 10 replications at the center point of the design was run, refer to appendix F. The 4 factors run in this experiment were determined from the factor screen of the 12 variables in the SAL PCS cost simulation. The ANOVA table for this experiment is shown in table 24.

The F test for model adequacy has a value of F=54.89 with a p-value of .0001. The significant factors were the accession rate (ACC), the overseas long tours (OSL TL), and the CONUS tour length (CON TL).

The check of the assumption of the residuals being normally distributed and having constant variance is shown in appendix H. The plots reveal no deviations from the assumptions.

Table 24 ANOVA Table for Linear Metamodel

Source of Variation	df	Sum of Squares	Mean Square	F	p
Model	4	21.19001	5.29750	54.89	.0001
A (ACC)	1	13.61947	13.61947	141.13	.0001
B (OS Sht2)	1	.08270	.08270	.86	.3651
C (CON TL)	1	1.63487	1.63487	16.94	.0005
D (OSL TL)	1	5.85296	5.85296	60.65	.0001
Error	21	2.02658	.09650		
Total	25	23.21658			
Lack of Fit	12	1.93101	.16092	15.15	.0002
Pure Error	9	.09557	.01062		

The lack-of-fit statistic (Cornell, 1984:12) was computed with F=15.15. The test for lack-of-fit of the linear model has a p-value of .0002, hence the null hypothesis of a planar surface is rejected. For additional assurance, the response from the center points replications were used to test for curvature in the data. This test had a p-value of 7×10^{-7}. Both tests have consistent results and the second degree polynomial will be constructed.

Quadratic Metamodel. A Box-Behnken design was used to build the second degree response surface for the significant factors from the factor screening experiment. The design is shown in appendix F. The model was judged significant with a p-value of .0001. The null hypothesis of equal factor effects is rejected. The ANOVA table is shown in table 25.

The design is not orthogonal, hence the response surface will include all the variables, even those that were not significant. The practically significant factors were A (the accession rate with a p-value of .0001), C (CONUS tour length with a p-value of .0001), D (overseas tour length with a p-value of .0001), B^2 with a p-value of .0004, C^2 with a p-value of .0018, and D^2 with a p-value of .0016. The response surface is described by the following equation:

$$
\begin{aligned}
Z=6.9873&+(.8404)A+(.908)B-(.3724)C-(.6391)D+(.0263)A^2 \\
&-(.1188)B^2+(.2893)C^2-(.23)D^2-(.0781)AB+(.009)AC-(.1367)AD \qquad (1) \\
&+(.0713)BC-(.0085)BD-(.0578)CD
\end{aligned}
$$

This result of the significant factors is consistent with the results of the linear model. But the quadratic model includes the B^2, C^2, and D^2 factors. The results are clear, *in the metamodel of the SAL career field attributes,* the accession rate, the overseas long tour lengths, and the CONUS tour lengths drive the PCS cost estimate.

Contour graphs of this surface, set at different levels, can be found in Appendix H. The model assumptions were checked with no departures from the model assumption of normality and constant variance. Equation 1 would not be the equation used to develop a cost estimate since insignificant parameters estimates are included. A Box-Behnken design is not orthogonal, hence a criteria for excluding insignificant parameters must be specified. Some criteria that are frequently chosen are minimum MSE or Mallow's CP. The Proc STEPWISE (SAS Institute, 1985) can be used to develope the "best" model.

Table 25   ANOVA Table for the Quadratic Metamodel

Source of Variation	df	Sum of Squares	Mean Square	F	p
Model	14	16.25727	1.16123	67.88	.0001
A (ACC)	1	8.47500	8.47500	495.39	.0001
B (OS Sht2)	1	.11530	.11530	6.74	.0234
C (CON TL)	1	1.66412	1.66412	97.27	.0001
D (OSL TL)	1	4.90095	4.90095	286.47	.0001
A*A	1	.01928	.01928	1.13	.3094
A*B	1	.02439	.02439	1.43	.2556
A*C	1	.00032	.00032	0.02	.8928
A*D	1	.07472	.07472	4.37	.0586
B*B	1	.39568	.39568	23.13	.0004
B*C	1	.02032	.02032	1.19	.2972
B*D	1	.00029	.00029	.02	.8992
C*C	1	.27135	.27135	15.86	.0018
C*D	1	.01334	.01334	.78	.3945
D*D	1	.28221	.28221	16.50	.0016
Error	12	.20529	.01711		
Total	26	16.46256			

Tour Length - Linear Model. A 2^3 factorial with 6 replicates at the center point of the design. The factors for this experiment were: A (CONUS tour length), B (overseas short tour length), and C (overseas long tour length). The design is shown in appendix F. The ANOVA table was constructed to test the significance of the factors in the fitted model, refer to table 26.

Table 26 ANOVA Table for Linear Model

Source of Variation	df	Sum of Squares	Mean Square	F	p
Model	3	4.09235	1.36412	11.82	.0013
A (CONUS)	1	.94539	.94539	8.19	.0169
B (OSS)	1	.09858	.09858	.85	.3771
C (OSL)	1	3.04839	3.04838	26.42	.0004
Error	10	1.15375	.11537		
Total	13	5.24611			
Lack of Fit	5	1.06954	.21392	12.70	.0072
Pure Error	5	.08421	.08421		

The F test for overall model fit (F=11.82) had a p-value of .0013, hence the null hypothesis of equal factor effects is rejected. From the sum of squares decomposition, factors A and C are significant with p-values of .0169 and .0004. Graphs of the model assumptions of normality and constant variance of the residuals are found in appendix H. The graph of the normal probability plot shows no deviations from the assumption of normality of the residuals. The graph of the predicted values versus the residuals does appear skewed, but this is probably due to the 6 runs at the center of the design. Otherwise the assumption of constant variance of the residuals seems valid.

Calculation of the lack-of-fit statistic will determine the "non-planarity in the response surface" (Cornell, 1984:12). Rejecting the null hypothesis that the surface is a plane will motivate the building of a second order response surface. The F test (F=12.7) has a p-value of .007 and we reject the null hypothesis of an adequate model fit. The center point runs were used to test for curvature in the data (Cornell, 1984:17). The test

statistic (F=41.87) has a p-value of .0013. Therefore the null hypothesis of no curvature in the data is rejected and this result is consistent with the lack-of-fit test.

Tour Length - Quadratic Model. The second degree response surface was constructed with the same factors that were in the linear model, without regard to factor significance. A Box-Behnken 3-factor design was used with the factor settings and response found in appendix F. The ANOVA table from this experiment is shown in table 27. The p-value for rejecting the null hypothesis of equal factor effects is .0021. The significant factors of the quadratic model are A with a p-value of .0014, C with a p-value of .001, and A^2 with a p-value of .0523, but all parameters will be included in the response surface because the Box-Behnken design is not orthogonal and each estimate of the coefficients of the response surface are dependent. The response surface is defined by the following equation,

$$Z=7.1691-(.35229)A-(.05017)B-(.6186)C+(.209)A^2$$
$$+(.20945)B^2+(.1189)C^2-(.0315)AB-(.0279)AC-(.0404)BC \qquad (2)$$

It is important to realize that equation 2 is not necessarily the "best" equation to use. A criteria must be chosen for including parameters in the model such as maximum adjusted R^2, minimun MSE, or Mallow's CP statistic. Once the criteria is established, then a stepwise regression technique such as Proc STEPWISE (SAS Institute, 1985) can be used. The contour graph for this response surface can be found in appendix G.

The assumptions of the model were checked and the normal probability plot shows that the assumption that the residuals are normally

distributed is reasonable. The graph of the predicted values versus the residuals shows that the assumption that residuals have constant variance is reasonable.

Table 27 ANOVA Table for Quadratic Model

Source of Variation	df	Sum of Squares	Mean Square	F	p
Model	9	4.30721	.47858	19.84	.0021
A (CONUS)	1	.99680	.99680	41.33	.0014
B (OSS)	1	.02013	.02013	.83	.4027
C (OSL)	1	3.06132	3.06132	126.92	.0001
A*A	1	.15487	.15487	6.42	.0523
B*B	1	.00828	.00829	.34	.2013
C*C	1	.05219	.05219	2.16	.7015
A*B	1	.00398	.00398	.16	.7343
A*C	1	.00311	.00311	.13	.6251
B*C	1	.00652	.00652	.27	
Error	5	.02412	.02412		
Total	14				

The results of the tour length metamodel are that the overseas long and CONUS tour lengths are the significant factors that drive the PCS cost in the tour length model. This is consistent with the metamodel of the SAL career field. This is reasonable since the overseas long and CONUS moves comprise the large part (over 95%) of the tours in the SAL PCS cost simulation.

Meeting Research Objectives

Both research objectives, constructing a methodology to experiment with tour lengths and constructing a metamodel of an AFSC, were

accomplished. The tour length model estimates the relative changes in PCS costs for the SAL career field as tour lengths are changed for 2 geographic regions. There were 3 factors in the tour length model: CONUS, overseas short, and overseas long tour lengths. The lack-of-fit test result motivated the use of the quadratic model to analyze how tour lengths impact the relative PCS cost changes of the SAL career field. From table 21, factor A (the CONUS tour length), C (the overseas long tour length), and A^2 were judged significant (alpha level $\approx$ .05). This result is not surprising since the number of overseas short tours is very small in the SAL career field. To show how PCS costs change when CONUS and overseas long tour lengths are lengthened, refer to appendix H (graph title: TL LM B=0). On the horizontal axis is the OSLTL (overseas long tour length) and on the vertical axis is the CONTL (CONUS tour length). Refer to table 18 for the ranges of these factors. Overseas short tour lengths were judged insignificant and set to 0 in equation 1. As both factors are changed, total PCS costs of the SAL career field are decreased. For example if CONUS and overseas long tour lengths are 3 years and overseas short tour lengths are 1 year, the approximate PCS cost for the SAL career field would be 8.63 million dollars. If both overseas long and CONUS tour lengths are lengthened to 4 years and overseas short tours are lengthened to 2 years, the total PCS cost would then be approximately 7.72 million dollars. This would be an 10.5% decrease in total PCS costs for the SAL career field.

The metamodel of the SAL career field was constructed using an input rate (accessions), tour lengths, and allocations of assignments aggregated by assignment classes and two geographic regions: CONUS and OS. A similar analysis can be done for the quadratic metamodel of the SAL career field

described in equation 2. Factors A (the accession rate), B (the overseas short tour in phase 2), C (the CONUS tour length), D (overseas long tour length), AD, B^2, C^2, and D^2 were significant (alpha level $\approx .05$). The 3 graphs in appendix H detail the PCS cost for different factor settings. Equation 2 could be used to develop a PCS cost for the SAL career field for any setting of the 4 factors. These results are consistent with the tour length model. The accession rate is used to replace the personnel separating from the Air Force, and by increasing the inventory of the SAL pilots, with the accession rate more PCS moves will occur. It seems reasonable that actual assignments allocations are not significant, but tour lengths are significant. In the experimentation region, varying the actual allocations did not change PCS costs significantely, since personnel will move somewhere and the costs used in this research were similar. Tour lengths limit the exchange and fill of jobs in the SAL PCS cost simulation and are significant in predicting PCS costs.

A word of caution is given to the interested reader, it is important to understand that the PCS cost estimates used in this research are not accurate estimates of the actual PCS costs for Air Force moves.

VI. Conclusions

In this chapter the implications of this research are discussed and explained. These implications will then be used to suggest some possible policy considerations for future research into PCS cost estimation and PCS cost modeling. Finally some recommendations for future academic research will be suggested.

Implications

The value of this research lies not in any answer or ability to predict a valid and credible PCS cost estimate, but in a methodology that has laid a foundation for future PCS cost estimation and modeling efforts. The PCS cost assumptions of this research made any type of validation impossible and the correct choice of detail and aggregation arbitrary. The results of the literature review show that all existing models that have the capability to incorporate some type of PCS cost were developed for other purposes than PCS cost estimation. PCS cost estimation may best be done by a different set of factors that are not usually included in a model of personnel systems. The methodology used in this research is a reasonable approach to analyze the output of a PCS cost model, but the current information of the PCS costs in the Air Force requires more study before any credibility is placed in a PCS cost model. The reader is reminded that the Navy Step 1 cost tables do not develop a validated PCS cost estimate, but the cost tables do give a relative PCS cost estimate for different types of PCS moves. The SAL PCS cost simulation can give information about relative PCS cost estimates for different tour lengths, accession rates, and different assignment allocations. Based on the SAL PCS cost simulation, it

is clear that the accession rate, the overseas long tour length and the CONUS tour lengths drive the PCS cost for the SAL career field. This seems reasonable since the amount of personnel that enter an AFSC will at some point increase the inventory. More people will mean more PCS moves. The overseas long and CONUS tour lengths comprise over 95% of the tours in the SAL PCS cost simulation, and they drive the PCS cost estimate. However, these results are based on the experimentation of the computer model developed in this research. The PCS cost data is questionable and the actual factors that drive PCS costs are unknown. A similar result was obtained for the tour length model. Overseas long and CONUS tour lengths were the significant factors in the tour length model.

Policy Recommendations

This research suggests three recommendations for Air Force policy makers. First, analysts must be made cognizant of the policies that are being considered or can be changed for a PCS cost model. Second, more research and analysis must be done on PCS cost estimation and prediction to understand the important factors in PCS costs. Third, that the modeling effort of this research continue and AFMPC decision makers should not settle on an existing model that was designed for a different purpose or contract to a commercial company until more information regarding PCS costing is known.

Recommendations for Future Research

Future research should focus on two aspects of PCS modeling. First, research needs to be done on PCS cost estimation to develop a reliable predictive model (such as regression with indicator variables) to develop a credible PCS cost estimate for different move attributes. A second

suggested area of research would study AFSCs to determine similar traits that might led to a better way to describe the "people" in a PCS cost model and help determine the proper level of detail and aggregation for PCS cost modeling.

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Appendix A: Retention Rates

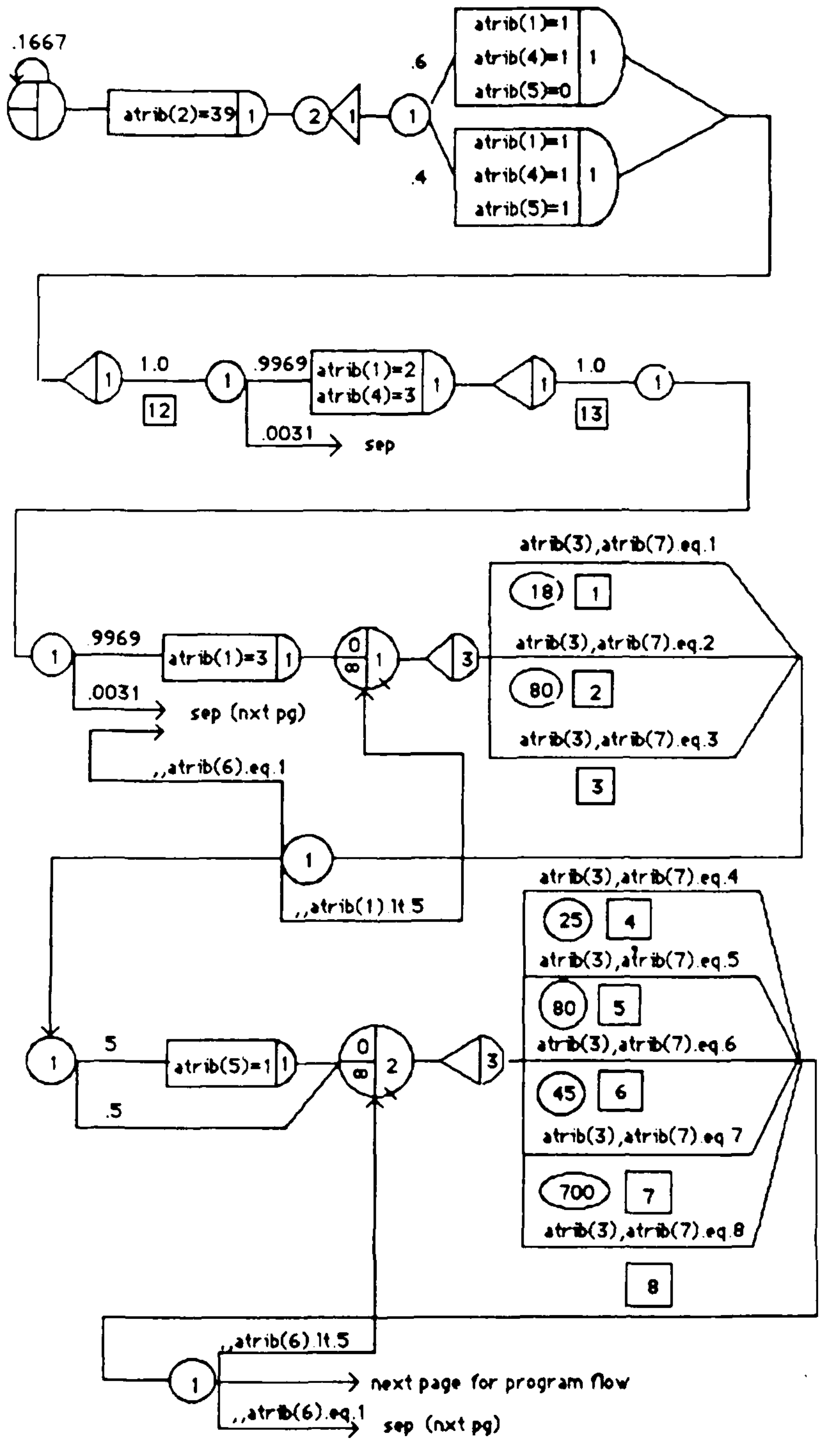
1986 Retention Rates		
Year Group	**Inventory**	**Retention Rate**
1986	86	.9969
1985	207	1.0000
1984	233	.9904
1983	261	.9932
1982	264	.9552
1981	292	.8150
1980	173	.7750
1979	120	.8737
1978	97	.8469
1977	118	.8596
1976	114	.9016
1975	86	.9550
1974	163	.9908
1973	154	.9810
1972	127	.9755
1971	169	.9831
1970	184	.9688
1969	214	.9496
1968	166	.6426
1967	150	.4196

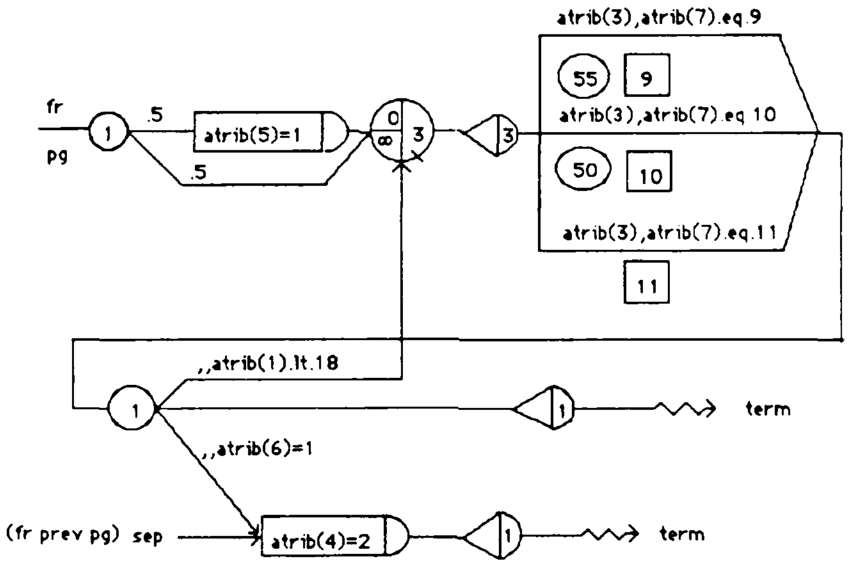
Appendix B: PCS Cost Used in Model

PCS COST TABLE - MOVE COST USED IN THE SAL PCS COST SIMULATION UNACCOMPANIED (IN DOLLARS)					
rank / move type	2ND LT	1ST LT	CAPT	MAJ	LTC
accession	954	0	0	0	0
conus - conus	0	1737	2207	1804	1720
os - conus conus - os	0	2907	3486	3814	3941

PCS COST TABLE - MOVE COST USED IN THE SAL PCS COST SIMULATION ACCOMPANIED (IN DOLLARS)					
rank / move type	2ND LT	1ST LT	CAPT	MAJ	LTC
accession	3955	0	0	0	0
conus - conus	0	4910	5286	5808	6820
os - conus conus - os	0	8349	9127	9785	10646

Appendix C: SLAM II Network Diagram




atrib(3),atrib(7).eq.9
55
9
fr
pg
1
.5
.5
atrib(5)=1
0
3
3
atrib(3),atrib(7).eq.10
50
10
atrib(3),atrib(7).eq.11
11
,,atrib(1).lt.18
1
1
term
,,atrib(6)=1
(fr prev pg) sep
atrib(4)=2
1
term

Appendix D: SLAM II Code

```
GEN,DM PERCICH,SAL 1,11/10/1987,,N,N,,,N,72;
LIMITS,3,7,10000;
STAT,1,ACCESSION COST;
STAT,2,SEPARATION COST;
STAT,3,TRAINING COST;
STAT,4,ROTATION COST;
STAT,5,OPERATIONAL COST;
NETWORK;
; CREATE A UPT CLASS 6 TIMES A YEAR WITH XX(6) STUDENTS
        CREATE,.1667;
        ASSIGN,ATRIB(2)=XX(6);
        UNBATCH,2,1;
; ASSIGN ACCESSION MOVE TYPE AND AN ACCOMPANIED STATUS
        GOON,1;
                ACT,,.4,A1;
                ACT,,.4,A2;
A1      ASSIGN,ATRIB(1)=1.0,ATRIB(4)=1.0,ATRIB(5)=1.0;
                ACT,,,L1;
A2      ASSIGN,ATRIB(1)=1.0,ATRIB(4)=1.0,ATRIB(5)=0.0;
;**************************************************
;*
;* UNDERGRADUATE PILOT TRAINING
;*
;**************************************************
L1      EVENT,1;
        ACT/12,1.0;UPT
        GOON,1;
                ACT,,.9969,A3;
                ACT,,.0031,SEP;
; ASSIGN MOVE TYPE TRAINING AND YEAR OF SERVICE=2;
A3      ASSIGN,ATRIB(1)=2.0,ATRIB(4)=3.0;
;**************************************************
;*
;* ADVANCED PILOT TRAINING
;*
;**************************************************
L2      EVENT,1;
```

```
        ACT/13,1.0;ADV TRN
        GOON,1;
                ACT,,.9969,A4;
                ACT,,.0031,SEP;
; ASSIGN YEAR OF SERVICE=3;
A4      ASSIGN,ATRIB(1)=3.0;
;*********************************************
;*
;* INITIAL PHASE - OPERATIONAL ASSIGNMENTS
;*
;*********************************************
Q1      QUEUE(1);
                ACT,,,;
        EVENT,3;
        GOON,1;
; THE AVAILABLE ASSIGNMENTS FOR PHASE 1
                ACT/1,ATRIB(3),ATRIB(7).EQ.1.0,L3;OS SHORT 1
                ACT/2,ATRIB(3),ATRIB(7).EQ.2.0,L3;OS LONG 1
                ACT/3,ATRIB(3),ATRIB(7).EQ.3.0,L3;CONUS 1
L3      GOON,1;
; ENTITY SEPARATES STAYS IN PHASE 1, OR GOES TO
; PHASE 2 (QUEUE(2))
                ACT,,ATRIB(6).EQ.1.0,SEP;
                ACT,,ATRIB(1).LT.5.0,Q1;
                ACT,,,;
        GOON,1;
                ACT,,.5,A4;
                ACT,,.5,Q2;
A4      ASSIGN,ATRIB(5)=1.0
;*********************************************
;*
;* INTERMEDIATE DEVELOPMENT PHASE - ASSIGNMENTS
;*
;*********************************************
Q2      QUEUE(2);
                ACT,,,;
        EVENT,3;
        GOON,1;
; THE AVAILABLE ASSIGNMENTS FOR PHASE 1
                ACT/4,ATRIB(3),ATRIB(7).EQ.4.0,L4;OS SHORT 2
                ACT/5,ATRIB(3),ATRIB(7).EQ.5.0,L4;OS LONG 2
                ACT/6,ATRIB(3),ATRIB(7).EQ.6.0,L4;AFIT/PME 2
```

```
                ACT/7,ATRIB(3),ATRIB(7).EQ.7.0,L4;CONUS 2
                ACT/8,ATRIB(3),ATRIB(7).EQ.8.0,L4;STAFF 2
L3      GOON,1;
; ENTITY SEPARATES STAYS IN PHASE 2, OR GOES TO
; PHASE 3 (QUEUE(3))
                ACT,,ATRIB(6).EQ.1.0,SEP;
                ACT,,ATRIB(1).LT.11.0,Q2;
                ACT,,,;
        GOON,1;
                ACT,,.5,A5;
                ACT,,.5,Q3;
A5      ASSIGN,ATRIB(5)=1.0;
;**********************************************
;*
;* ADVANCED DEVELOPMENT PHASE - ASSIGNMENTS
;*
;**********************************************
Q3      QUEUE(3);
                ACT,,,;
        EVENT,3;
        GOON,1;
; THE AVAILABLE ASSIGNMENTS FOR PHASE 3
                ACT/9,ATRIB(3),ATRIB(7).EQ.9.0,L4;AFIT/PME 3
                ACT/10,ATRIB(3),ATRIB(7).EQ.10.0,L4;OPS 3
                ACT/11,ATRIB(3),ATRIB(7).EQ.11.0,L4;STAFF 3
L5      GOON,1;
; ENTITY SEPARATES STAYS IN PHASE 3, OR
; LEAVES THE MODEL
                ACT,,ATRIB(6).EQ.1.0,SEP;
                ACT,,ATRIB(1).LT.18.0,Q3;
                ACT,,,;
        EVENT,1;
        TERM;
;**********************************************
;*
;* SEPARATIONS
;*
;**********************************************
; ASSIGN A SEPARATION MOVE TYPE
SEP     ASSIGN,ATRIB(4)=2.0;
        EVENT,1;
        TERM;
```

```
    ENDNETWORK;
INIT,0.0,25.0;
FINISH;
```

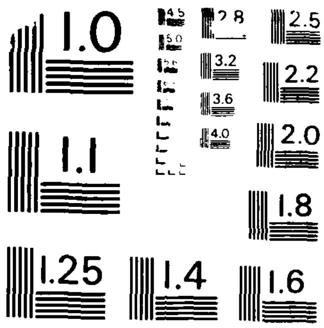
Appendix E: <u>Fortran Source Code</u>

```
      PROGRAM MAIN
C*****************************************************
C
C ATRIB(1)=YEAR OF SERVICE
C ATRIB(2)=LAST TOUR TYPE
C
C THE ASSIGNMENT INDICATORS IN ATRIB(2) AND ATRIB(4)
C
C       1=ACCESSION
C       2=SEPARATION
C       3=TRAINING
C       4=OVERSEAS SHORT
C       OVERSEAS LONG
C       6=CONUS
C
C ATRIB(3)=TOUR LENGTH
C ATRIB(4)=NEXT TOUR TYPE
C
C ATRIB(5)=ACCOMPANIED INDICATOR=0=UNACCOMPANIED
C                                 1=ACCOMPANIED
C
C ATRIB(6)=SEPARATION INDICATOR=0=NOT SEPARATING
C                              =1=SEPARATING
C
C ATRIB(7)=ACTIVITY (ASSIGNMENT) CHOICE
C
C ITIS=PRESENT YEAR OF MILITARY SERVICE
C XRET=VALUE OF THE RETENTION PROBABILITY
C XTOUR=UNIFORM(0,1) DRAW FOR SEPARATION CALCULATION
C
C XOSS=TOUR LENGTH OF OVERSEAS SHORT
C XOSL=TOUR LENGTH OF OVERSEAS LONG
C XCON=TOUR LENGTH OF CONUS
C
C XX(1)=ACCESSION MOVE COST
C XX(2)=SEPARATION MOVE COST
C XX(3)=TRAINING MOVE COST
C XX(4)=ROTATIONAL MOVE COST
```

```
C XX(5)=OPERATIONAL MOVE COST
C XX(6)=NUMBER OF SAL PILOTS PER UPT CLASS
C
C XTOTCST=TOTAL MOVE COST IN YEAR
C XTOTMV=TOTAL OF MOVES IN YEAR
C XACC=TOTAL ACCESSION MOVE COST
C  XSEP=TOTAL SEPARATION COST
C XTRN=TOTAL TRAINING MOVE COST
C ROT=TOTAL TRAINING MOVE COST
C XOP=TOTAL OPERATIONAL MOVE COST
C
C IACCY=NUMBER OF ACCESSIONS PER YEAR
C IOSS1=NUMBER OF OVERSEAS SHORT TOURS-PHASE 1
C IOSL1=NUMBER OF OVERSEAS LONG TOURS -PHASE 1
C IOSS2=NUMBER OF OVERSEAS SHORT TOURS-PHASE 2
C IOSL2=NUMBER OF OVERSEAS LONG TOURS-PHASE 2
C ITR2=NUMBER OF TRAINING SLOTS-PHASE 2
C ICON2=NUMBER OF CONUS TOURS-PHASE 2
C ITR3=NUMBER OF TRAINING TOURS-PHASE 3
C IOPS3=NUMBER OF OPERATIONAL TOURS-PHASE 3
C
C***********************************************

      DIMENSION NSET(130000)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/QSET(130000)
      EQUIVALENCE (NSET(1),QSET(1))
      NNSET=130000
      NCRDR=5
      NPRNT=6
      NTAPE=7
      NPLOT=2
      OPEN(11,STATUS='NEW',FILE='TRAN.DAT',FORM='FORMATTED')
      CALL SLAM
      STOP
      END


      SUBROUTINE EVENT (I)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
```

```
      COMMON/UCOM1/RET(20),COST(5,5,2)XOSL,XOSS,XCON,IACCY,IOSS1,
      1,IOSL1,IOSS2,IOSL2,ICON2,ITR3,IOP3

      GO TO (1,2,3,4) I

1     CALL MOVE
      RETURN

C CLEAR ALL STATISTICAL ARRAYS AT THE START OF EVERY YEAR
C SCHEDULE THE NEXT CALL TO SUBROUTINE CLEAR IN 1 YEAR
2     CALL CLEAR
      CALL SCHDL(2,1.0,ATRIB)
      RETURN

3     ASSIGN

4     CALL TOURL
      RETURN
      END


      SUBROUTINE INTLC
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
      1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/RET(20),COST(5,5,2)XOSL,XOSS,XCON,IACCY,IOSS1,
      1,IOSL1,IOSS2,IOSL2,ICON2,ITR3,IOP3

C SET UP MOVING COSTS BY MOVE TYPE, RANK, AND AN ACCOMPANIED STATUS
      DATA COST/954,0,0,0,1737,2907,0,2207,3486,0,1804,3814,0,1720
      1,3941,3955,0,0,0,4910,8349,0,5286,9127,0,5808,9785,0,6820,
      1,10646/

C SET UP RETENTION RATES FOR YEAR OF SERVICE 1 - 20
      DATA RET/.9969,1.0,.9904,.9932,.9952,.815,.775,.8737,.8469
      1,.8596,.9016,.995,.9908,.981,.9755,.9831,.9688,.9496,.6426
      1,.4196/

C READ AND INITIALIZE THE ASSIGNMENT ALLOCATIONS AND TOUR LENGTHS
      READ(NCRDR,100)IACCY,IOSS1,IOSL1,IOSS2,IOSL2,ITR2,ICON2,ITR3
      1,IOPS3,XOSL,XOSS,XCON
100   FORMAT(9I5,3F4.1)
```

AD-A189 751 MODELING THE PERMANENT CHANGE OF STATION MOVING COSTS 2/2
OF STRATEGIC AIRLIFT PILOTS(U) AIR FORCE INST OF TECH
WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. D M PERCICH
UNCLASSIFIED DEC 87 AFIT/GOR/ENS/87D-15 F/G 12/4 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1963

```
C SET CLASS RATE INTO UPT
      XX(6)=INT(IACCY/6)

C INITIALIZE THE INITIAL GROUP
      DO 10 I=1,253
      ATRIB(1)=2.0
      CALL FILEM(1,ATRIB)
      ATRIB(1)=3.0
      CALL FILEM(1,ATRIB)
      ATRIB(1)=4.0
      CALL FILEM(1,ATRIB)
10    CONTINUE

C INITIALIZE THE INTERMEDIATE DEVELOPMENT PHASE
      DO 20 I=1,152
      ATRIB(1)=5.0
      CALL FILEM(2,ATRIB)
      ATRIB(1)=6.0
      CALL FILEM(2,ATRIB)
      ATRIB(1)=7.0
      CALL FILEM(2,ATRIB)
      ATRIB(1)=8.0
      CALL FILEM(2,ATRIB)
      ATRIB(1)=9.0
      CALL FILEM(2,ATRIB)
      ATRIB(1)=10.0
      CALL FILEM(2,ATRIB)
20    CONTINUE

C INITIALIZE THE ADVANCED DEVELOPMENT PHASE
      DO 30 I=1,148
      ATRIB(1)=11.0
      CALL FILEM(3,ATRIB)
      ATRIB(1)=12.0
      CALL FILEM(3,ATRIB)
      ATRIB(1)=13.0
      CALL FILEM(3,ATRIB)
      ATRIB(1)=14.0
      CALL FILEM(3,ATRIB)
      ATRIB(1)=15.0
      CALL FILEM(3,ATRIB)
      ATRIB(1)=16.0
```

```
      CALL FILEM(3,ATRIB)
30    CONTINUE

C CLEAR STATISTICAL ARRAYS IN YEAR 1
      CALL SCHDL(2,1.00001,ATRIB)

      RETURN
      END




      SUBROUTINE TOURL
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
      1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/RET(20),COST(5,5,2)XOSL,XOSS,XCON,IACCY,IOSS1,
      1,IOSL1,IOSS2,IOSL2,ICON2,ITR3,IOP3

C SET THE YEAR OF SERVICE
      ITIS=INT(ATRIB(1))

C**************************************************
C
C DETERMINE THE MOVE TYPE  3=TRAINING
C                          4=OVERSEAS SHORT
C                          5=OVERSEAS LONG
C                          6=CONUS
C
C ASSIGN TOUR LENGTH IN ATRIB(3)
C ASSIGN SEPARATION STATUS IN ATRIB(6)=0=NOT SEPARATING
C                                     =1=SEPARATING
C
C**************************************************

C FOR A TRAINING MOVE ASSIGN A 1 AND 1/2 YEAR TOUR LENGTH
C AND DO NOT LET THE MEMBER SEPARATE
      IF(ATRIB(4).EQ.3.0) THEN
            ATRIB(3)=1.5
            ATRIB(6)=0.0

C FOR A OVERSEAS SHORT MOVE ASSIGN A TOUR LENGTH OF XOSS
```

```
C AND DO NOT LET THE MEMBER SEPARATE
      ELSEIF(ATRIB(4).EQ.4.0) THEN
            ATRIB(3)=XOSS
            ATRIB(6)=0.0

C FOR AN OVERSEAS LONG TOUR DETERMINE IF THE TOUR WILL LAST FULL
C TERM OR BE CURTAILED BY AN SEPARATION
      ELSEIF (ATRIB(4).EQ.5.0) THEN
C UNIFORM DRAW FOR RETENTION CALCULATION
      XTOUR=UNFRM(0.0,1.0,1)
      XRET=1.0
C CALCULATE RETENTION PROBABILITY FOR SEPARATIONS PER YEAR
C FROM YEAR 1 TO XOSL
      DO 10 I=1,XOSL
            XRET=XRET*RET(ITIS+I)
C IF PRODUCT OF RETENTION RATES ARE LESS THAN XTOUR
C THEN ASSIGN A TOUR LENGTH OF I YEARS AND SEPARATE MEMBER
            IF (XRET.LT.XTOUR) THEN
                  ATRIB(3)=I
                  ATRIB(6)=1.0
                  GO TO 999
            ENDIF
10    CONTINUE
      ATRIB(3)=XOSL
      ATRIB(6)=0.0

C FOR AN CONUS LONG TOUR DETERMINE IF THE TOUR WILL LAST FULL
C TERM OR BE CURTAILED BY AN SEPARATION
      ELSEIF (ATRIB(4).EQ.6.0) THEN
C UNIFORM DRAW FOR RETENTION CALCULATION
      XTOUR=UNFRM(0.0,1.0,1)
      XRET=1.0
C CALCULATE RETENTION PROBABILITY FOR SEPARATIONS PER YEAR
C FROM YEAR 1 TO XCON
      DO 20 I=1,XCON
            XRET=XRET*RET(ITIS+I)
C IF PRODUCT OF RETENTION RATES ARE LESS THAN XTOUR
C THEN ASSIGN A TOUR LENGTH OF I YEARS AND SEPARATE MEMBER
            IF (XRET.LT.XTOUR) THEN
                  ATRIB(3)=I
                  ATRIB(6)=1.0
                  GO TO 999
```

```
            ENDIF
20     CONTINUE
       ATRIB(3)=XCON
       ATRIB(6)=0.0
       ENDIF

999    RETURN
       END




       SUBROUTIN ASSIGN
       COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
       1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
       COMMON/UCOM1/RET(20),COST(5,5,2)XOSL,XOSS,XCON,IACCY,IOSS1,
       1,IOSL1,IOSS2,IOSL2,ICON2,ITR3,IOP3

       ATRIB(2)=ATRIB(4)

C ASSIGN ENTITY INTO THE INITIAL PHASE IF THE YEAR OF
C SERVICE IS LESS THAN 5 YEARS
       IF (ATRIB(1).LT.5.0) THEN
C CHECK OVERSEAS SHORT TOURS WITH LAST TOUR NOT OVERSEAS
            IF(NNACT(1).LT.IOSS1.AND.
       1    (ATRIB(2).NE.4.0.OR.ATRIB(2).NE.5.0)) THEN
                 ATRIB(4)=4.0
                 ATRIB(7)=1.0

C CHECK OVERSEAS LONG TOURS WITH LAST TOUR NOT OVERSEAS
            ELSEIF(NNACT(2).LT.IOSL1.AND.
       1    (ATRIB(2).NE.4.0.OR.ATRIB(2).NE.5.0)) THEN
                 ATRIB(4)=5.0
                 ATRIB(7)=2.0
C DEFAULT ALL TOURS TO CONUS
            ELSE
                 ATRIB(4)=6.0
                 ATRIB(7)=3.0
            ENDIF

C ASSIGN ENTITY INTO THE ADVANCED DEVELOPMENT PHASE IF THE YEAR OF
C SERVICE IS LESS THAN 11 YEARS
```

```
      ELSEIF (ATRIB(1).LT.11.0) THEN
C CHECK OVERSEAS SHORT TOURS WITH LAST TOUR NOT OVERSEAS
            IF(NNACT(4).LT.IOSS2.AND.
     1      (ATRIB(2).NE.4.0.OR.ATRIB(2).NE.5.0)) THEN
                  ATRIB(4)=4.0
                  ATRIB(7)=4.0
C CHECK OVERSEAS LONG TOURS WITH LAST TOUR NOT OVERSEAS
            ELSEIF(NNACT(5).LT.IOSL2.AND.
     1      (ATRIB(2).NE.4.0.OR.ATRIB(2).NE.5.0)) THEN
                  ATRIB(4)=5.0
                  ATRIB(7)=5.0
C CHECK TRAINING SLOTS WITH LAST TOUR NOT TRAINING
            ELSEIF(NNACT(6).LT.ITR2.AND.ATRIB(2).NE.3.0) THEN
                  ATRIB(4)=3.0
                  ATRIB(7)=6.0
C CHECK CONUS AND IF OPEN THEN FILL
            ELSEIF(NNACT(7).LT.ICON2) THEN
                  ATRIB(4)=6.0
                  ATRIB(7)=7.0
C DEFAULT ALL OTHERS TO STAFF TOURS
            ELSE
                  ATRIB(4)=6.0
                  ATRIB(7)=8.0

C ASSIGN ENTITY INTO THE ADVANCED DEVELOPMENT PHASE IF THE YEAR OF
C SERVICE IS LESS THAN 20 YEARS
      ELSE
C CHECK TRAINING SLOTS WITH LAST TOUR NOT TRAINING
            IF(NNACT(9).LT.IITR3.AND.ATRIB(2).NE.3.0) THEN
                  ATRIB(4)=3.0
                  ATRIB(7)=9.0
C IF OPERATIONS TOUR OPEN THEN FILL
            ELSEIF (NNACT(10).LT.IOP3) THEN
                  ATRIB(4)=6.0
                  ATRIB(7)=10.0
C DEFAULT ALL TOURS TO STAFF
            ELSE
                  ATRIB(4)=6.0
                  ATRIB(7)=11.0
            ENDIF
      ENDIF
```

```
C ASSIGN A TOUR LENGTH
      CALL TOURL

C CALCULATE A MOVING COST
      CALL MOVE

C UPDATE THE YEAR OF SERVICE WHEN THE NEXT TOUR IS COMPLETE
      ATRIB(1)=ATRIB(1)+ATRIB(3)

      RETURN
      END




      SUBROUTINE MOVE
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/RET(20),COST(5,5,2)XOSL,XOSS,XCON,IACCY,IOSS1,
     1,IOSL1,IOSS2,IOSL2,ICON2,ITR3,IOP3

C DETERMINE THE RANK OF THE ENTITY MOVING FROM
C THE YEAR OF SERVICE IN ATRIB(1)

C 2ND LTS
      IF (ATRIB(1).LT.2.0) THEN
            IMOVE=1
C 1ST LTS
      ELSEIF (ATRIB(1).LT.4.0) THEN
            IMOVE=2
C CAPTAINS
      ELSEIF (ATRIB(1).LT.10.0) THEN
            IMOVE=3
C MAJORS
      ELSEIF (ATRIB(1).LT14.0) THEN
            IMOVE=4
      ELSE
            IMOVE=5
      ENDIF

C ASSIGN AN ACCOMPANIED STATUS
```

```
      IACC=ATRIB(5)+1

C COLLECT MOVING COSTS BY MOVE TYPE FOUND IN ATRIB(4)
C ACCESSION MOVES
      IF (ATRIB).EQ.1.0) THEN
            IMOVE=1
            XX(1)=COST(IMOVE,IRANK,IACC)
            CALL COLCT(XX(1),1)

C SEPARATION MOVE
      ELSEIF (ATRIB(2).EQ.4.0.OR.ATRIB(2).EQ.5.0) THEN
C SEPARATION FROM OVERSEAS TO CONUS
                  IMOVE=3
            ELSE
C SEPARATION FROM CONUS TO CONUS
                  IMOVE=2
            ENDIF

            XX(2)=COST(IMOVE,IRANK,IACC)
            CALL COLCT(XX(2),2)

C FROM A CONUS TRAINING LOCATION
      ELSEIF (ATRIB(2).EQ.3.0) THEN
C FROM TRAINING MOVE TO OVERSEAS
            IF (ATRIB(4).EQ.4.0.OR.ATRIB(4).EQ.5.0) THEN
                  IMOVE=3
            ELSE
C FROM TRAINING TO CONUS
                  IMOVE=2
            ENDIF

            XX(3)=COST(IMOVE,IRANK,IACC)
            CALL COLCT(XX(3),3)

C MOVING TO TRAINING
      ELSEIF (ATRIB(4).EQ.3.0) THEN
            IF (ATRIB(2).EQ.4.0.OR.ATRIB(2).EQ.5.0) THEN
                  IMOVE=3
C TO TRAINING FROM OVERSEAS
            ELSE
C TO TRAINING FROM CONUS
                  IMPVE=2
```

```
            ENDIF

            XX(3)=COST(IMOVE,IRANK,IACC)
            CALL COLCT(XX(3),3)

C CONUS TO CONUS MOVE
        ELSEIF (ATRIB(2).EQ.6.0.AND.ATRIB(4).EQ.6.0) THEN
            IMOVE=2
            XX(4)=COST(IMOVE,IRANK,IACC)
            CALL COLCT(XX(4),4)

C OVERSEAS TO CONUS OR CONUS TO OVERSEASMOVE
        ELSE
            IMOVE=3
            XX(5)=COST(IMOVE,IRANK,IACC)
            CALL COLCT(XX(5),5)

        ENDIF

        RETURN
        END




        SUBROUTINE OTPUT
        COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
        1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
        COMMON/UCOM1/RET(20),COST(5,5,2)XOSL,XOSS,XCON,IACCY,IOSS1,
        1,IOSL1,IOSS2,IOSL2,ICON2,ITR3,IOP3

        XTOTMV=0.0
        XTOTCST=0.0

C TOTAL INVENTORY AT END OF YEAR
        IVEN=NNACT(1)+NNACT(2)+NNACT(3)+NNACT(4)+NNACT(5)+NNACT(6)
        1+NNACT(7)+NNACT(8)+NNACT(9)+NNACT(10)+NNACT(11)+NNACT(12)+
        1+NNACT(13)

C CALCULATE MOVING COSTS BY MOVE CATEGORY
        XACC=CCNUM(1)*CCAVG(1)
```

```
      XSEP=CCNUM(2)*CCAVG(2)
      XTRN=CCNUM(3)*CCAVG(3)
      XROT=CCNUM(4)*CCAVG(4)
      XOP=CCNUM(5)*CCAVG(5)

C TOTAL MOVE COST AND NUMBER
      XTOTMV=CCNUM(1)+CCNUM(2)+CCNUM(3)+CCNUM(4)+CCNUM(5)
      XTOTCST=XACC+XSEP+XTRN+XROT+XOP

C PRINT TO FILE
      WRITE(11,100)IACCY,IOSS1,IOSL1,IOSS2,IOSL2,ITR2,ICON2,ITR3,IOP3
      WRITE(11,150)XOSL,XOSS,XCON
      WRITE(11,200)XTOTMV,XTOTCST,INVEN
100   FORMAT(' ',9I5)
150   FORMAT(' ',3F5.1)
200   FORMAT(' ',F20.0,2 X,F20.0,2 X,I10)

      RETURN
      END
```

Appendix F: Experimental Designs

Factor Screen Stage 1					
2^5 Factoral - Factor Screen Stage 1					
A	B	C	D	E	Response
-1	-1	-1	-1	-1	7.03081
1	-1	-1	-1	-1	9.02895
-1	1	-1	-1	-1	7.28663
1	1	-1	-1	-1	9.29921
-1	-1	1	-1	-1	7.74651
1	-1	1	-1	-1	9.54994
-1	1	1	-1	-1	7.85005
1	1	1	-1	-1	9.73446
-1	-1	-1	1	-1	7.15238
1	-1	-1	1	-1	9.26265
-1	1	-1	1	-1	7.52775
1	1	-1	1	-1	9.18461
-1	-1	1	1	-1	7.70597
1	-1	1	1	-1	9.85080
-1	1	1	1	-1	7.80521
1	1	1	1	-1	9.80165
-1	-1	-1	-1	1	5.21908
1	-1	-1	-1	1	6.83202
-1	1	-1	-1	1	5.44509
1	1	-1	-1	1	7.12557
-1	-1	1	-1	1	5.64463
1	-1	1	-1	1	7.36623
-1	1	1	-1	1	5.85258
1	1	1	-1	1	7.77604
-1	-1	-1	1	1	5.33605
1	-1	-1	1	1	6.68126
-1	1	-1	1	1	5.46299
1	1	-1	1	1	6.97184
-1	-1	1	1	1	5.88516
1	-1	1	1	1	7.05262
-1	1	1	1	1	5.63338
1	1	1	1	1	7.18472

Factor Screen Stage 2								
2^{8-3} Fractional Factorial - Factor Screen Stage 2								
A	B	C	D	E	F	G	H	Response
-1	-1	-1	-1	-1	-1	-1	-1	7.18287
1	1	1	1	-1	-1	-1	-1	9.82876
1	-1	1	-1	1	1	1	1	7.04979
-1	1	-1	1	1	1	1	1	5.82650
1	1	1	1	1	1	1	-1	9.24703
-1	-1	-1	-1	1	1	1	-1	6.71906
-1	1	-1	1	-1	-1	-1	1	6.70919
1	-1	1	-1	-1	-1	-1	1	8.26502
-1	-1	-1	-1	1	-1	-1	1	6.15455
1	1	1	1	1	-1	-1	1	8.69727
1	-1	1	-1	-1	1	1	-1	8.81533
1	-1	1	-1	1	-1	-1	-1	9.28896
1	1	1	1	-1	1	1	1	7.41948
-1	-1	-1	-1	-1	1	1	1	5.27340
-1	1	-1	1	1	-1	-1	-1	7.60266
-1	1	-1	1	-1	1	1	-1	7.07795
-1	-1	1	1	-1	1	-1	-1	6.86014
1	1	-1	-1	-1	1	-1	-1	9.14248
1	-1	-1	1	1	-1	1	1	8.15963
-1	1	1	-1	1	-1	1	1	6.62675
1	1	-1	-1	1	-1	1	-1	9.70798
-1	-1	1	1	1	-1	1	-1	7.44141
-1	1	1	-1	-1	1	-1	1	5.88207
1	-1	-1	1	-1	1	-1	1	7.17556
-1	-1	1	1	1	1	-1	1	5.68105
1	1	-1	-1	1	1	-1	1	7.71744
1	-1	-1	1	-1	-1	1	-1	9.47289
-1	1	1	-1	-1	-1	1	-1	7.57512
1	1	-1	-1	-1	-1	1	1	8.18272
-1	-1	1	1	-1	-1	1	1	6.51303
-1	1	1	-1	1	1	-1	-1	7.16726
1	-1	-1	1	1	1	-1	-1	9.10412

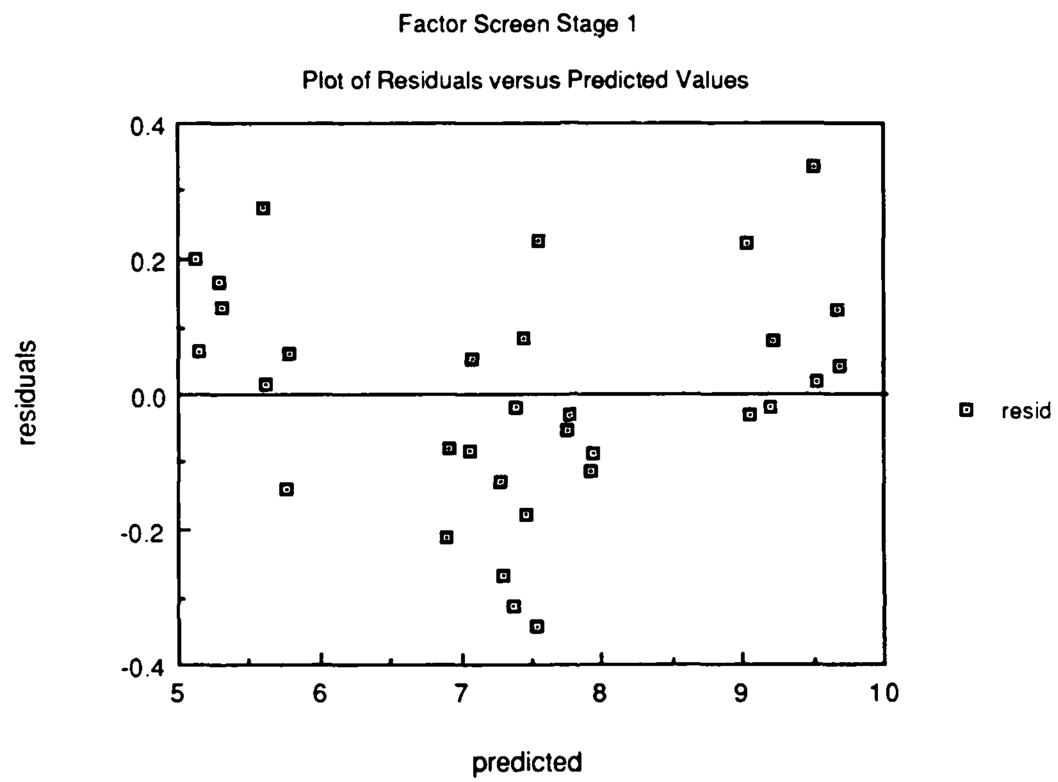
Metamodel - Linear Model				
2^4 Factorial with Center Point Reps				
A	B	C	D	Response
- 1	- 1	- 1	- 1	7.25405
1	- 1	- 1	- 1	9.56390
- 1	1	- 1	- 1	7.45105
1	1	- 1	- 1	9.55662
- 1	- 1	1	- 1	6.99189
1	- 1	1	- 1	8.44005
- 1	1	1	- 1	6.96139
1	1	1	- 1	9.03849
- 1	- 1	- 1	1	6.48189
1	- 1	- 1	1	8.07884
- 1	1	- 1	1	6.56749
1	1	- 1	1	8.02227
- 1	- 1	1	1	5.61097
1	- 1	1	1	7.42212
- 1	1	1	1	5.71923
1	1	1	1	7.67749
0	0	0	0	6.81468
0	0	0	0	7.02190
0	0	0	0	6.98864
0	0	0	0	7.04286
0	0	0	0	7.15009
0	0	0	0	7.12358
0	0	0	0	7.09531
0	0	0	0	7.17481
0	0	0	0	7.10093
0	0	0	0	7.03668

Metamodel - Quadratic Model				
Box-Behnken 4 Factor Design				
A	B	C	D	Response
-1	-1	0	0	5.92620
1	-1	0	0	7.78002
-1	1	0	0	6.21463
1	1	0	0	7.75612
0	0	0	0	8.36926
0	0	-1	-1	7.95302
0	0	1	-1	7.22464
0	0	-1	1	6.57738
0	0	0	0	6.94485
-1	0	0	-1	6.88796
1	0	0	-1	8.90453
-1	0	0	1	5.82514
1	0	0	1	7.29501
0	-1	-1	0	7.42666
0	1	-1	0	7.51716
0	-1	1	0	6.62495
0	1	1	0	7.00052
0	0	0	0	6.88309
-1	0	-1	0	7.02395
1	0	-1	0	8.60739
-1	0	1	0	5.96252
1	0	1	0	7.58197
0	-1	0	-1	7.58868
0	1	0	-1	7.82845
0	-1	.0	1	6.36748
0	1	0	1	6.57339
0	0	0	0	7.13382

Tour Length - Linear Model			
Design for 2^3 factorial with center point replications			
A (CONUS)	B (OS Long)	C (OS Short)	Response
-1	-1	-1	8.41757
1	-1	-1	8.1508
-1	1	-1	8.22693
1	1	-1	7.74098
-1	-1	1	7.27854
1	-1	1	6.66433
-1	1	1	7.51924
1	1	1	6.13595
0	0	0	6.98002
0	0	0	7.08880
0	0	0	7.11848
0	0	0	7.18816
0	0	0	6.84405
0	0	0	7.16292

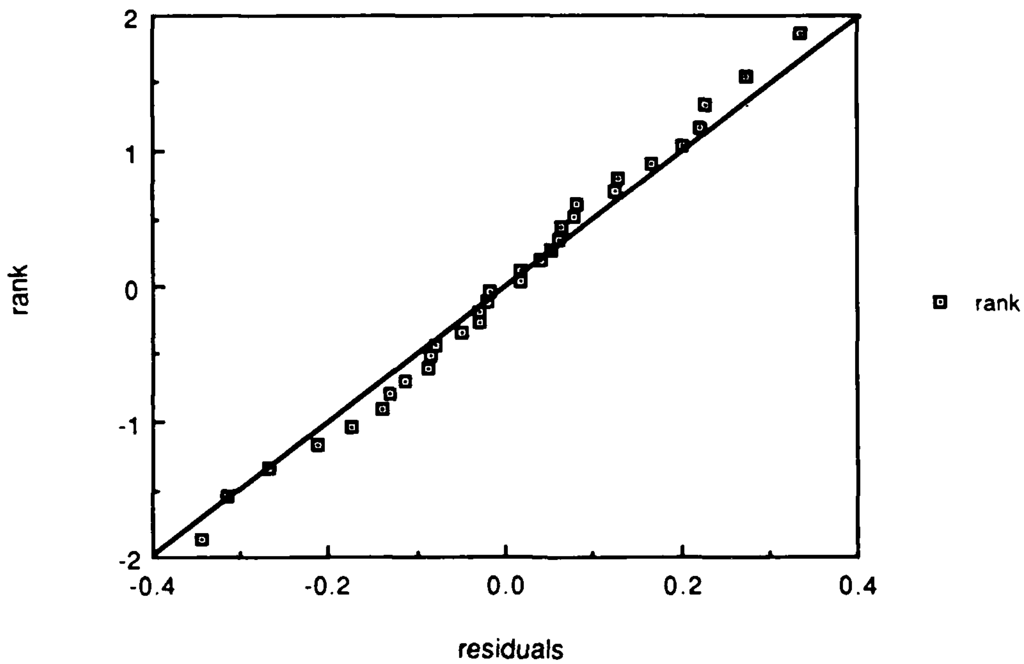
Tour Length - Quadratic Model			
Box-Behnken design for 3 factors			
A (CONUS)	B (OS Long)	C (OS Short)	Response
-1	-1	0	7.69744
1	-1	0	7.08367
-1	1	0	7.66039
1	1	0	6.92051
0	0	0	7.25426
-1	0	-1	8.34016
1	0	-1	7.66078
-1	0	1	7.38986
1	0	1	6.59900
0	0	0	7.10247
0	-1	-1	8.07481
0	1	-1	7.89343
0	-1	1	6.52426
0	1	1	6.50586
0	0	0	7.15060

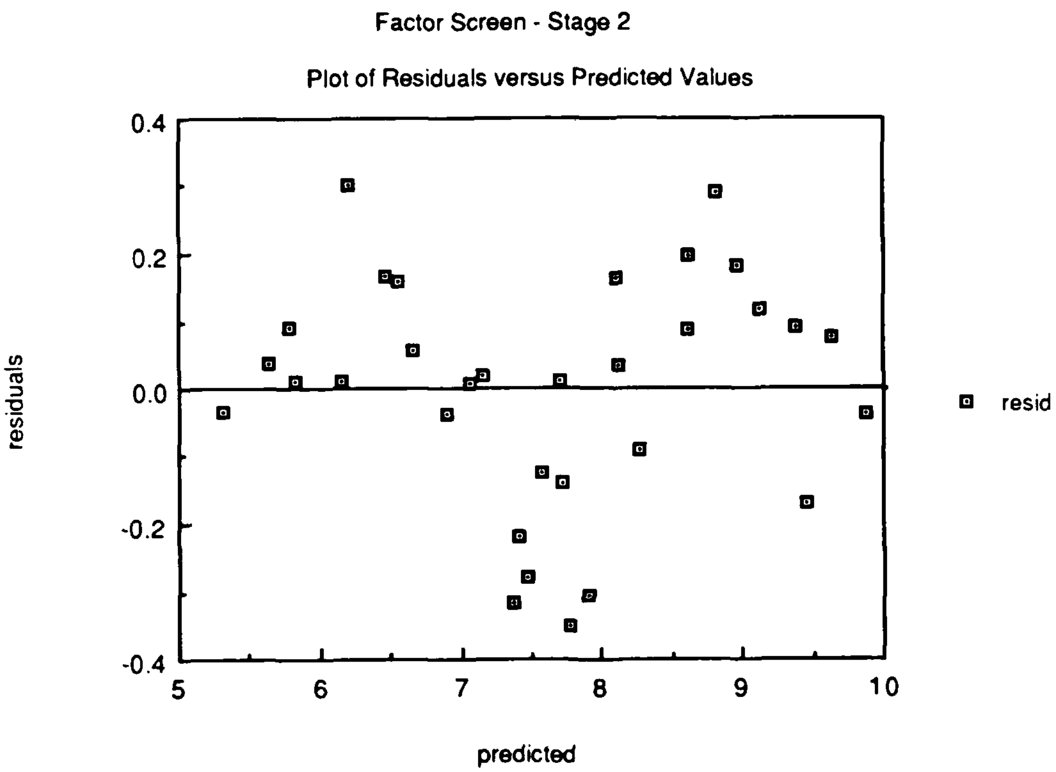
Appendix G: Graphs of ANOVA Assumptions

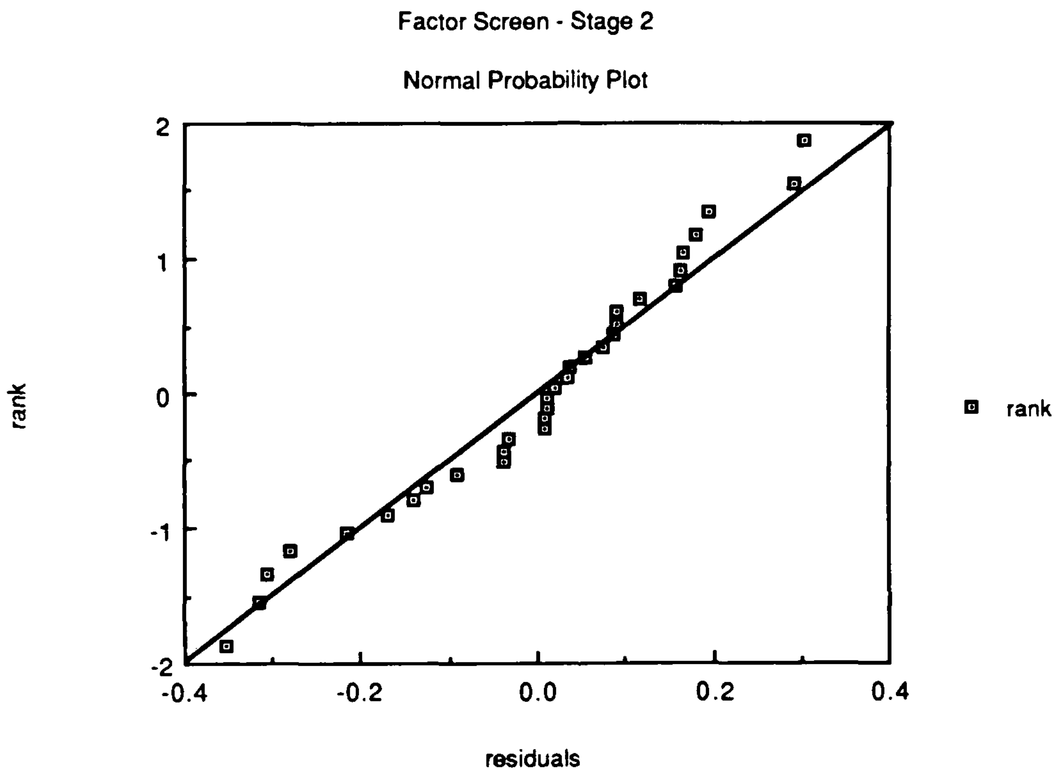


Factor Screen - Stage 1

Normal Probability Plot

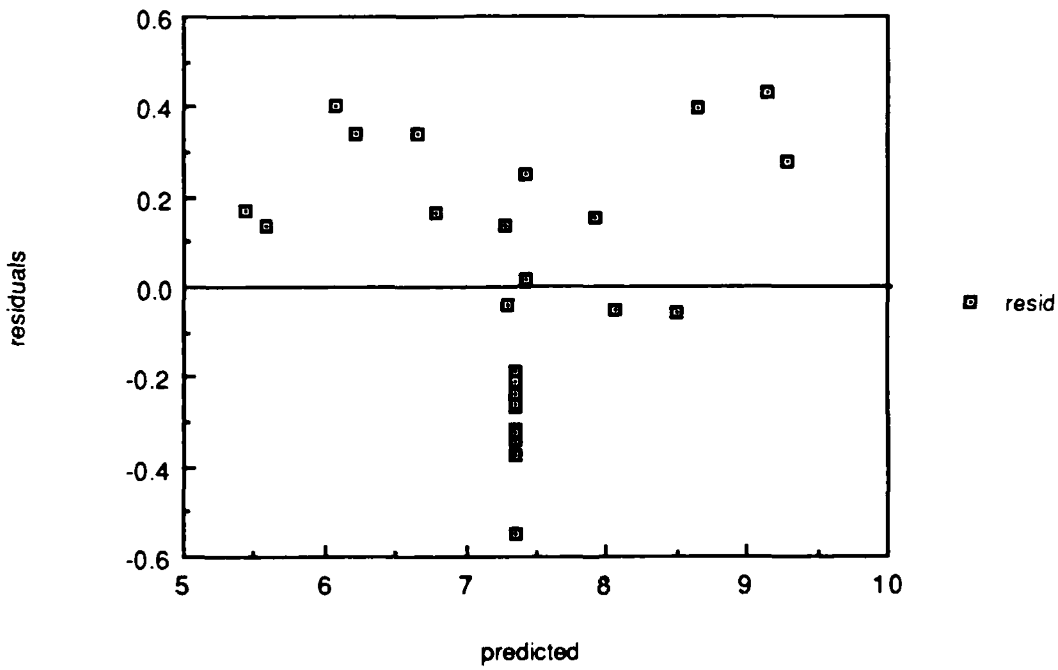


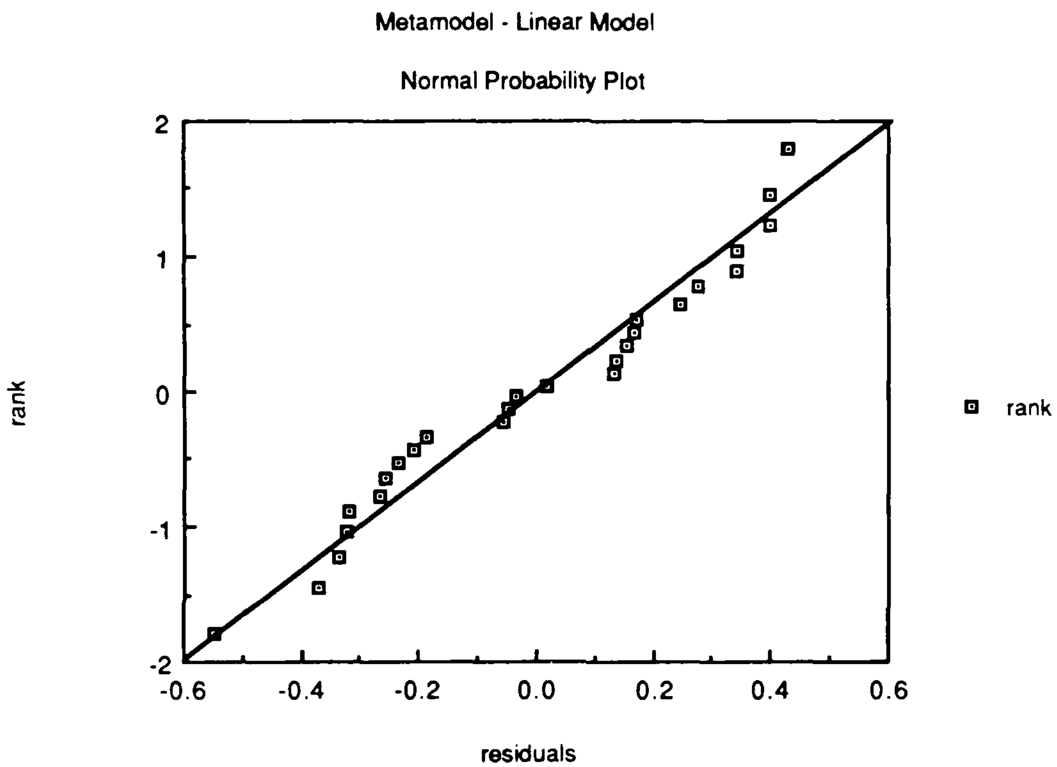

Factor Screen - Stage 2
Plot of Residuals versus Predicted Values
0.4
0.2
0.0
-0.2
-0.4
residuals
5
6
7
8
9
10
predicted
resid


Factor Screen - Stage 2
Normal Probability Plot
rank
2
1
0
-1
-2
-0.4
-0.2
0.0
0.2
0.4
residuals
rank

Metamodel - Linear Model

Plot of Residuals versus Predicted Values

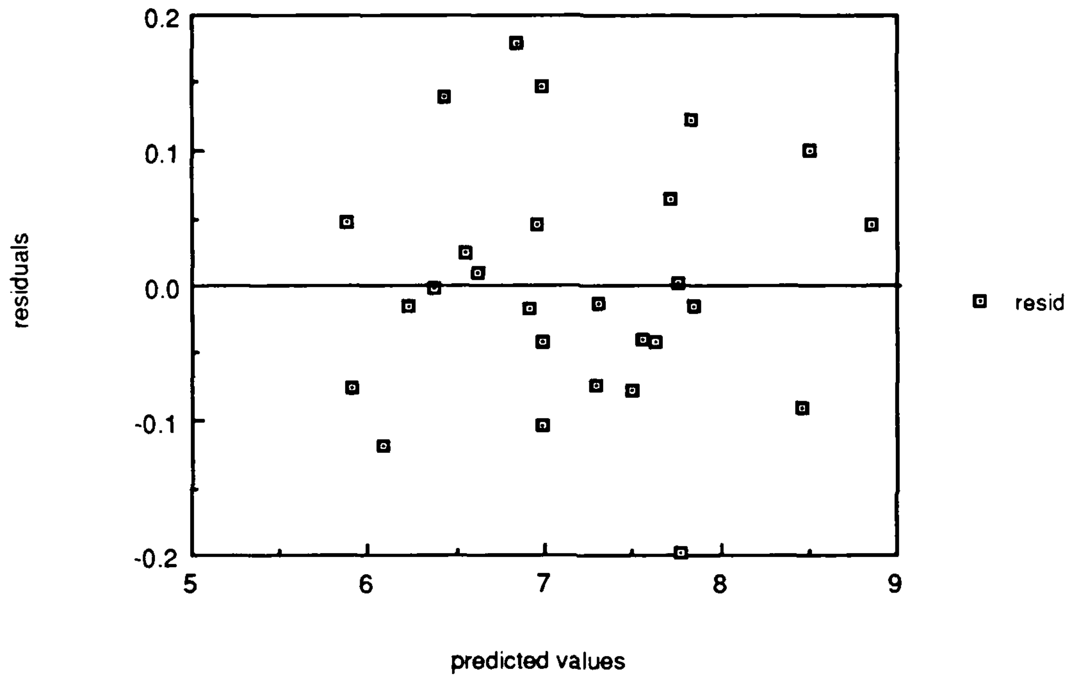




Metamodel - Linear Model
Normal Probability Plot
2
1
0
-1
-2
rank
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
residuals
rank

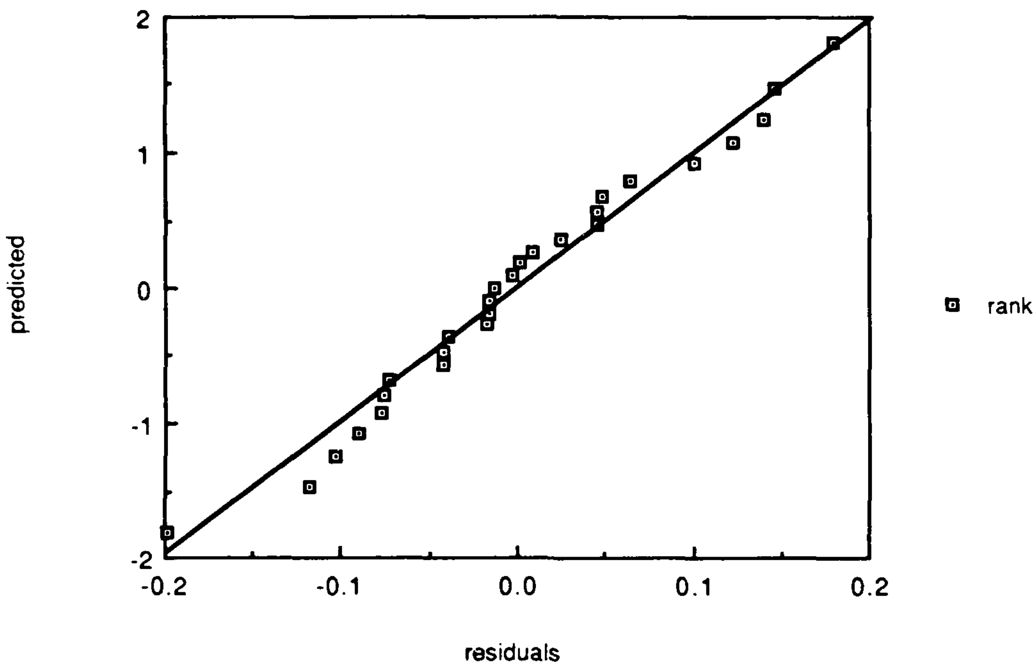
Metamodel - Quadratic Model

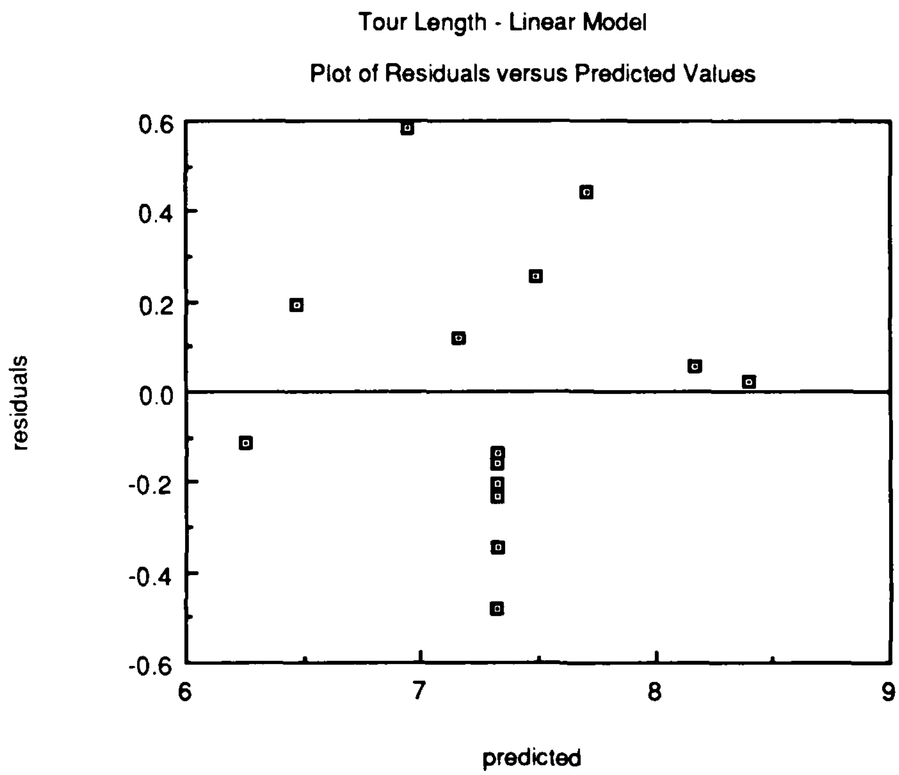
Plot of Residuals versus Predicted Values

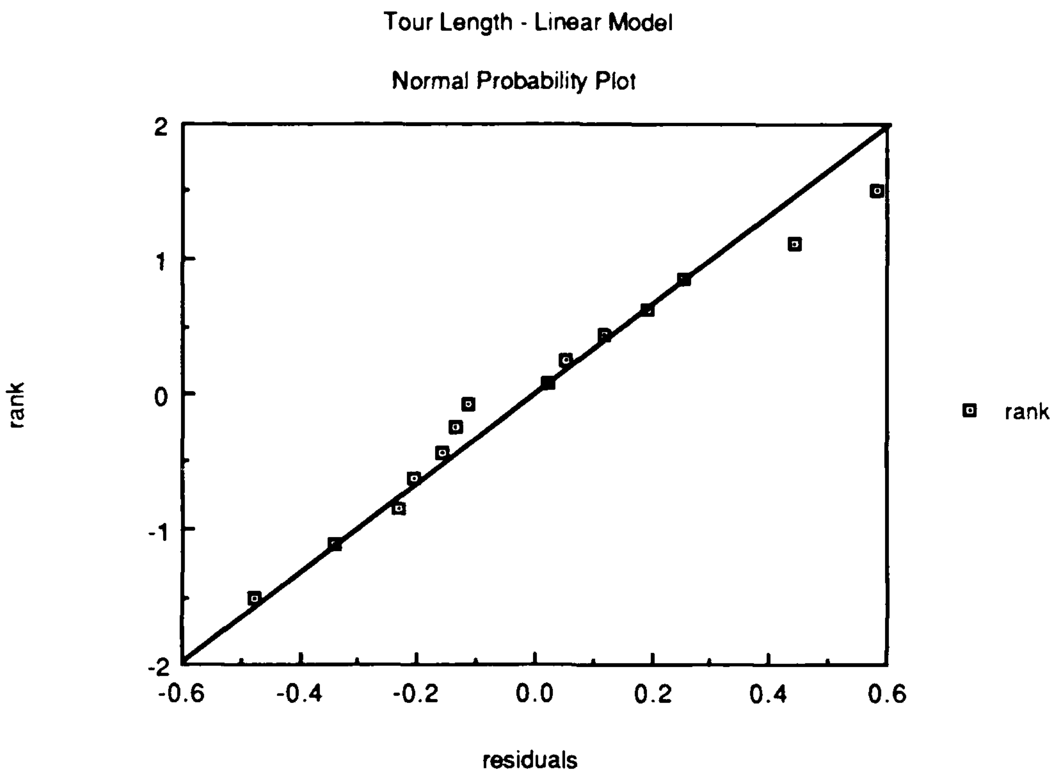


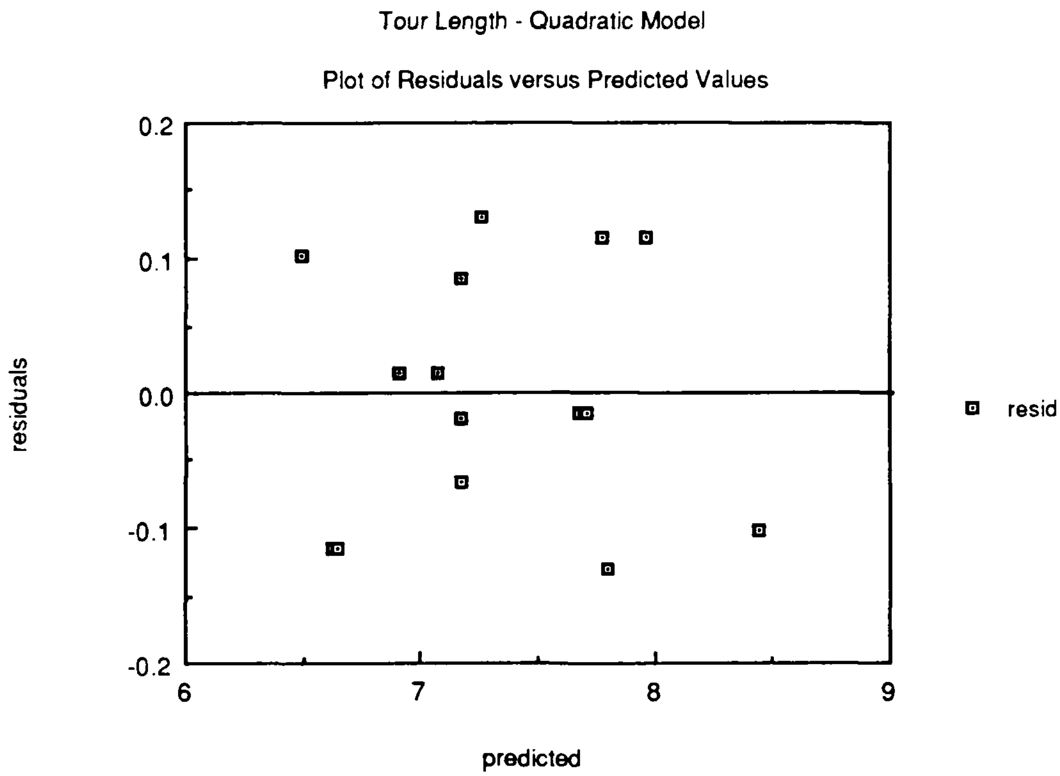
Metamodel - Quadratic Model

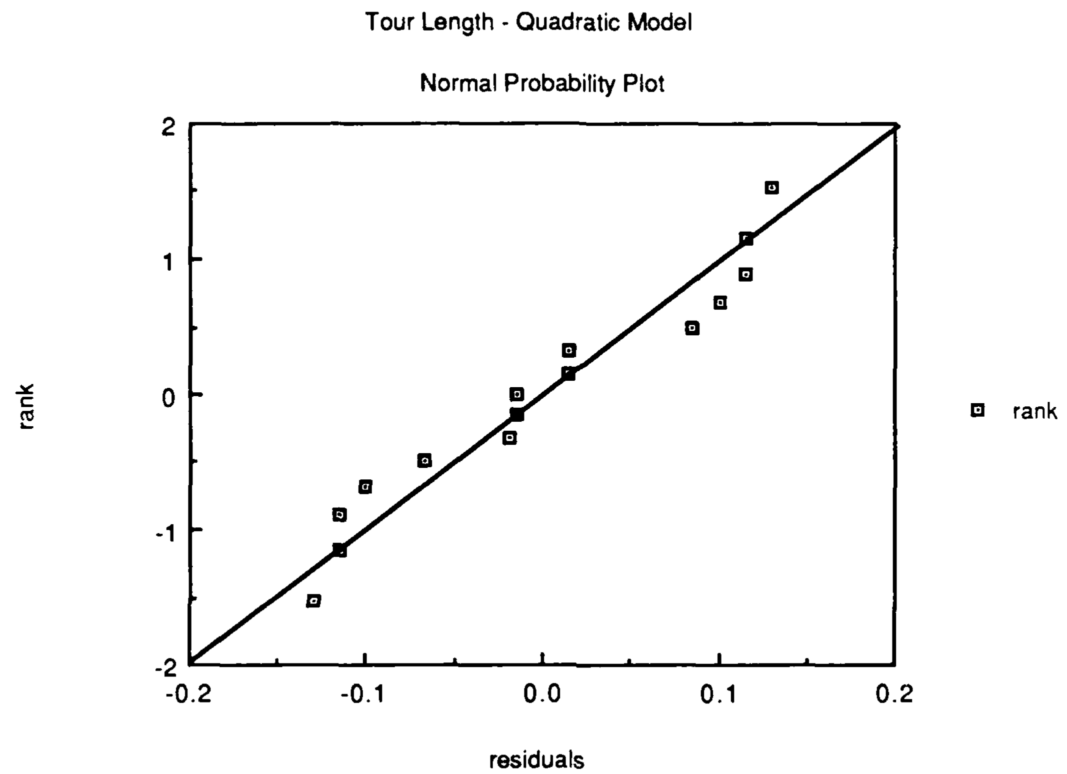
Plot of Residuals versus Predicted Values




Tour Length - Linear Model
Plot of Residuals versus Predicted Values
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
6
7
8
9
residuals
predicted


Tour Length - Linear Model
Normal Probability Plot
rank
residuals
2
1
0
-1
-2
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
rank

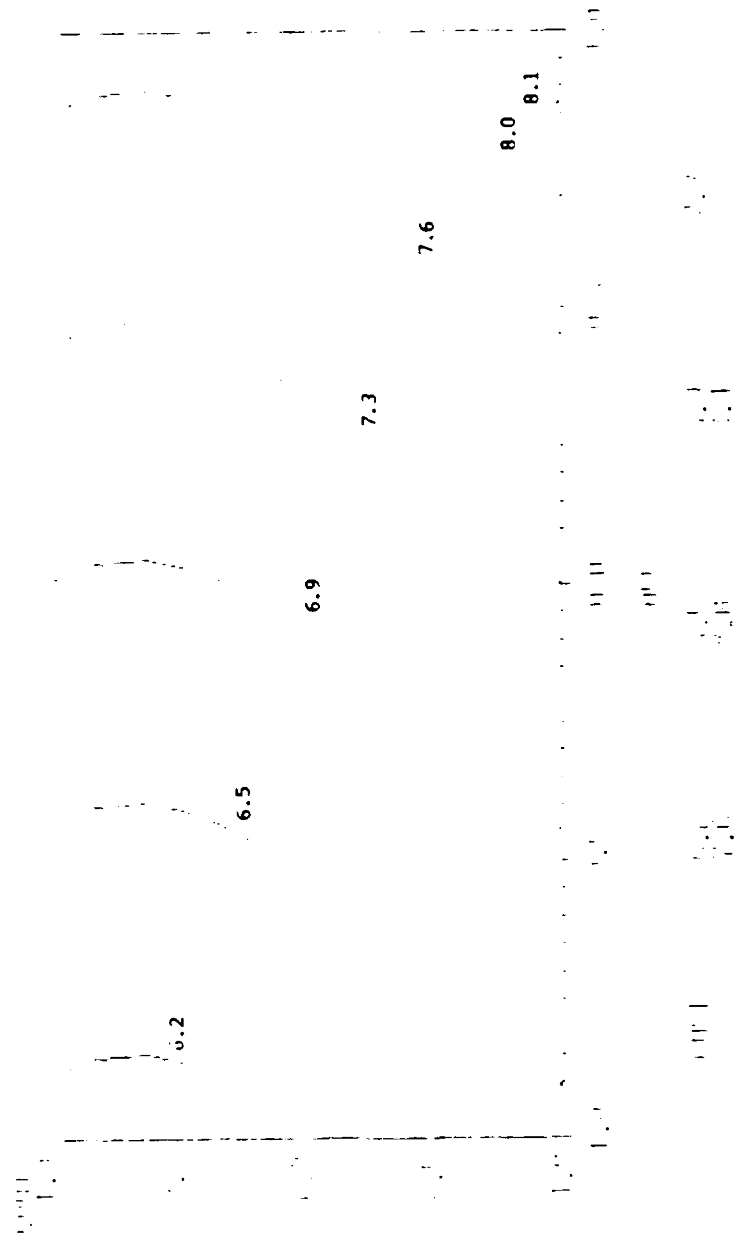

Tour Length - Quadratic Model
Plot of Residuals versus Predicted Values
0.2
0.1
0.0
-0.1
-0.2
residuals
6
7
8
9
predicted
resid


Tour Length - Quadratic Model
Normal Probability Plot
2
1
0
-1
-2
-0.2
-0.1
0.0
0.1
0.2
rank
residuals
rank

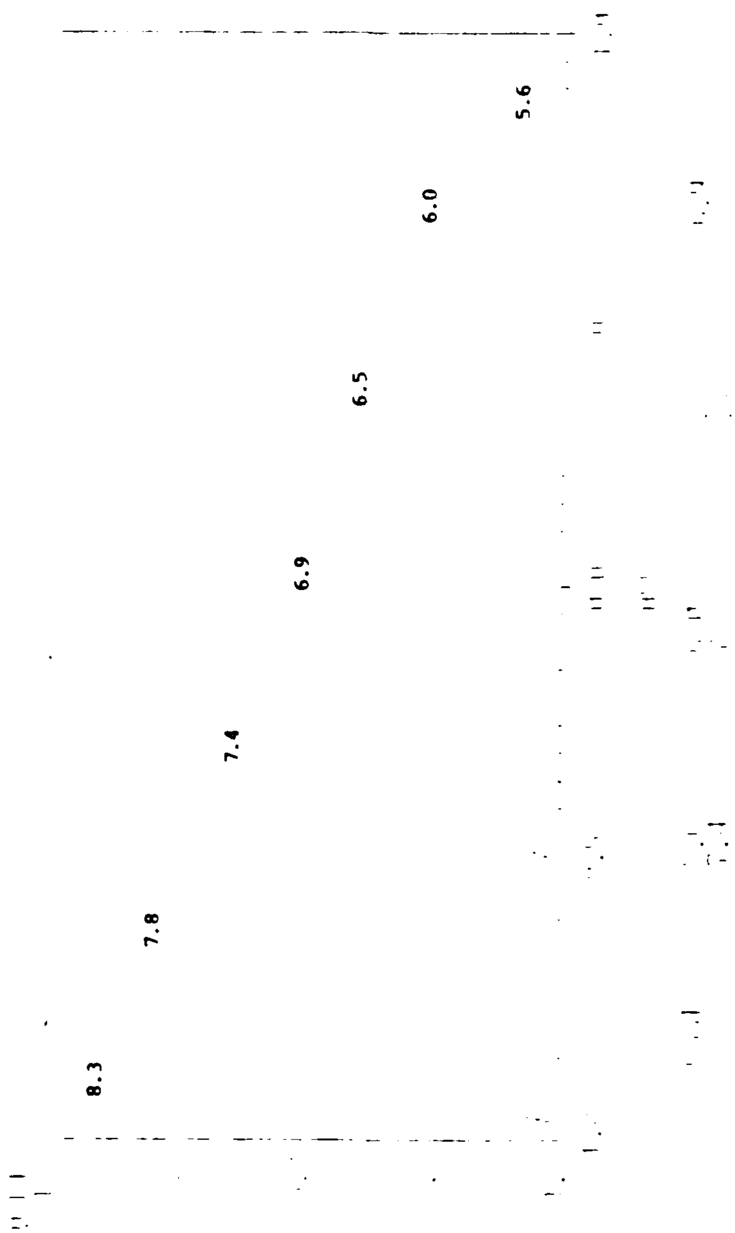
Appendix H: Response Surface Contour Graphs
Linear Tour Length Model Factor B at Middle Level

Metamodel: Factors A=0 and B=0

Metamodel: Factors B=0 and C=0

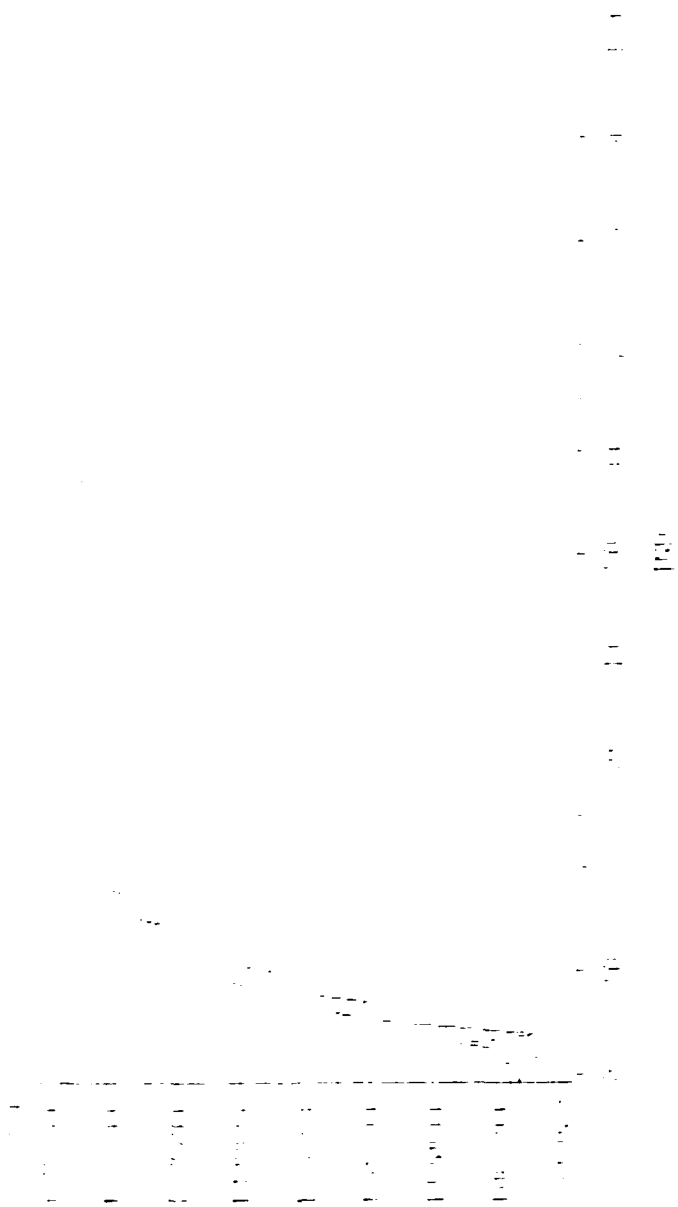


Metamodel: Factors B=0 and D=0

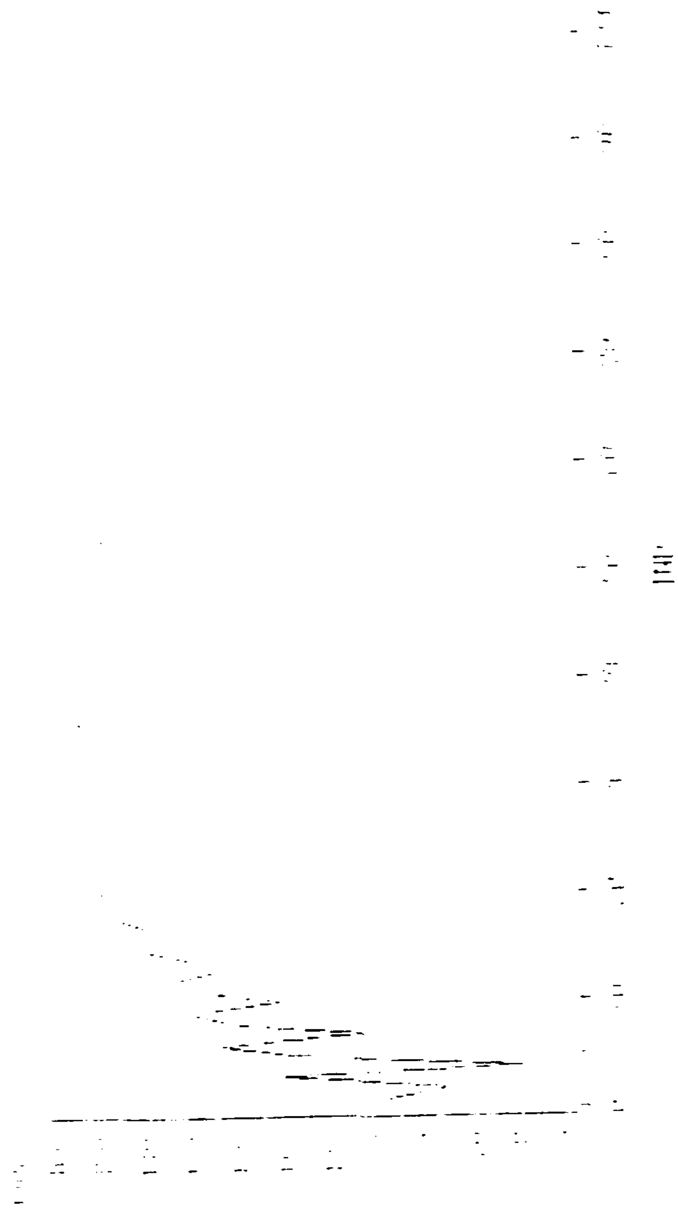


Appendix I: Steady State Graphs

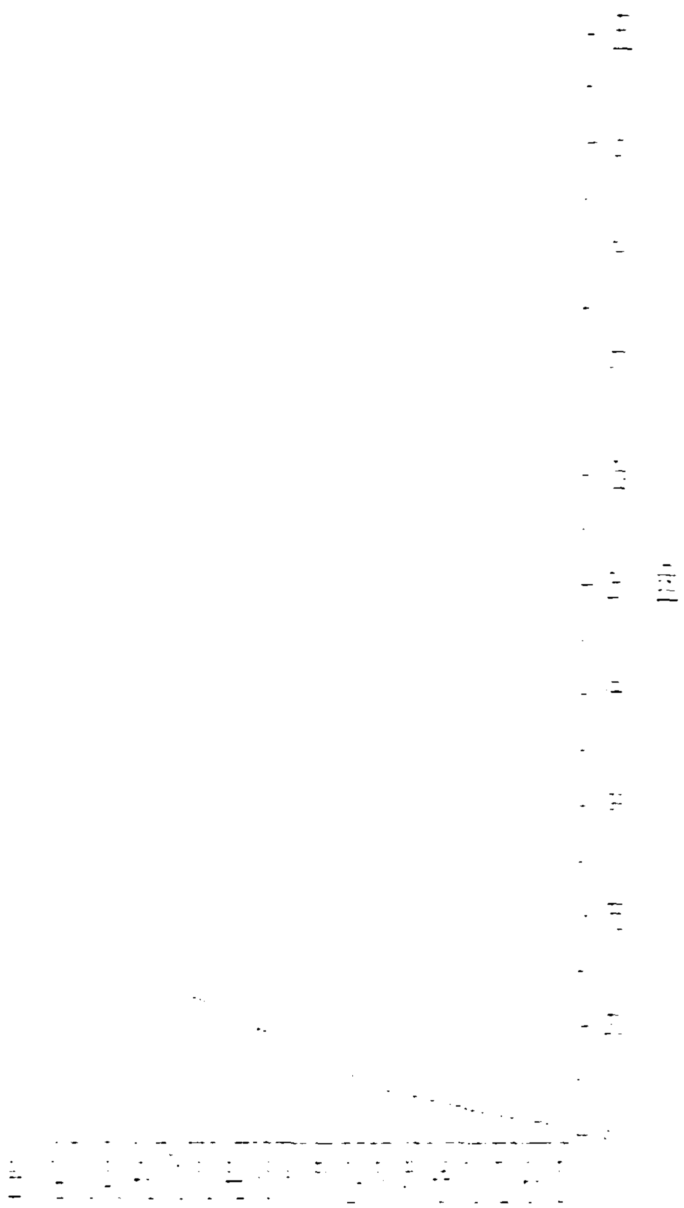
Total PCS Cost per Year



Total Number of Moves per Year



Inventory of Entities per Year



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This thesis lays a foundation for PCS cost modeling for the United States Air Force. A SLAM II computer simulation was developed to simulate the career progression of the strategic airlift pilot career field, from accession into the Air Force until their 20th year of military service. The simulation considers the moves that a strategic airlift pilot will experience in a career based on Air Force regulations and current Air Force projections for the career field.

Two response surfaces are developed from the different experimental designs used in the cost simulation. The first is a second order utilizing the attributes of the strategic airlift pilot career field such as accession rate, assignment allocations and tour lengths. The second is a second order response surface utilizing the CONUS, overseas short and overseas long tour lengths.

Thesis Advisor: Major Kenneth W. Bauer, PhD
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